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ANTARCTICA: A HISTORY OF ANTARCTIC DISCOVERY.*

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INTRODUCTION.

After lying dormant for nearly half a century, interest in the Antarctic has at last reawakened, and several expeditions are now fitting out for South Polar research. While looking forward hopefully, therefore, to an increase of knowledge, it is also necessary to look backward and review the results already accomplished. For not long since Sir Clements R. Markham, P.R.G.S., proposed in the *Geographical Journal*, for November, 1899, to divide the Antarctic into four quadrants, each covering 90° of longitude, and to bear English names. The advantages of this proposition on the score of convenience are not self-evident. Moreover, it is only just to remember that, besides Englishmen, mariners of many other nations have made discoveries in the Antarctic. A letter that I wrote on this matter was

*Copyright 1900, by Edwin Swift Balch.

published in the *Nation*, New York, May 10, 1900, and also in the *Evening Post*, New York, of the same date. Up to that time I had made no special study of Antarctic geography, and discovered then how difficult it was to find accurate data. This monograph may be considered as an amplification of the letter, and I trust that the references in it, at least, will help other geographers to investigate the subject and bring out the whole truth.

Americans ought to take an interest in the Antarctic, for American explorers have done good work there. Not only were Sheffield, Fanning, Palmer, Pendleton, Johnson, Morrell and Smiley among the first to follow and make new discoveries in the tracks of the Hollander, Dirk Gerritz, but also it was an American, Charles Wilkes, of the United States Navy, who first announced, on March 11 and 13, 1840, that there is a mass of land, continental in dimensions, in Antarctica. It is the only discovery of the kind since that of Australia, and, in the writer's opinion, it places Wilkes at the head of American explorers.

A number of gentlemen have helped me in one way or another in this work. I am especially indebted to Dr. Frederick A. Cook, of Brooklyn; Prof. George Davidson, of San Francisco; Mr. George C. Hurlbut, of New York; Mr. P. Lee Phillips and Captain C. C. Todd, U.S.N., of Washington, D. C.; and Mr. Henry G. Bryant, Mr. F. L. Garrison, Prof. Angelo Heilprin, Mr. Edward S. Miles, Mr. Bunford Samuel, Dr. William H. Wahl and Mr. Harvey M. Watts, of Philadelphia.

I. VOYAGES LEADING FROM A BELIEF TO A DISBELIEF IN A TERRA AUSTRALIS INCOGNITA.

That some great land existed near the South Pole seems to have been guessed at centuries ago. Ptolemy is accredited with having held and expressed some such idea. It is hard to see on what the belief rested, but it lasted until Captain Cook's second voyage. Amerigo Vespucci may have unintentionally helped to foster the notion. In his letter to Pier Soderini, Gonfalonier of the Republic of Florence, he narrates in his third voyage* that his ship reached

* "The First Four Voyages of Amerigo Vespucci," London, Bernard Quaritch, 1893, page 39.

52° south latitude, and that they sighted a new and rough coast, along which they sailed for twenty leagues. Varnhagen* has shown that this land is almost surely South Georgia, and Vespucci, therefore, has perhaps some claim to be looked on as the first discoverer of land in Antarctica.† However this may be, on many maps of the sixteenth century there is a *Terra Australis Nondum Cognita* or Great Southern Continent marked as stretching from Tierra del Fuego to Australia. In the map of Orontius Fine, made in 1531, and published in the Paris *Grynaeus* of 1532, there is charted a *Terra Australis recenter inventa, sed nondû plenè cognita;* and in the Mercator map of 1538, this land is also shown and inscribed as a certainty.‡ The voyages of the pilot, Juan Fernandez, who, in about 1563, certainly reached the island which bears his name, and who, in about 1576, may have reached the coast of New Zealand, helped to strengthen the belief, as he was accredited with having touched this unknown continent.§

The first positive discovery of land in Antarctica appears to have been made accidentally by a Dutchman, Dirk Gerritz,

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* Varnhagen, F. A. de: "Amerigo Vespucci, son Caractère, ses Ecrits," etc., Lima, 1865, page 111.

† I am not sure who first applied the name Antarctica to the South Polar regions; it may have been Sir John Murray. In this monograph I use the term to denote the portion of the earth round the South Pole, including land, islands, ice and ocean. Geographers are not yet agreed as to the limits of the Antarctic. It is an open question whether South Georgia and Bouvet and Kerguelen Islands belong to it. Undoubtedly, however, it includes everything south of 60° south latitude; although, perhaps, no hard-and-fast line can be drawn. Of no part of the world is so little known as about the Antarctic, and about none has there been so little interest taken. This is probably partly due to its distance from the centers of thought, and partly also to its lack of life, both of animals and men. The human interest is entirely absent in the desolate wastes of the South Pole, and not the least curious fact connected with them is that there is no apparent record of any woman having passed beyond 60° south latitude.

‡ These two maps are reproduced in "The Continent of America," by John Boyd Thacher. New York: W. E. Benjamin, 1896.

§ Burney, James, Captain in the Royal Navy: "A Chronological History of the Voyages and Discoveries in the South Sea or Pacific Ocean," London, Vol. I, 1803, pages 274, 300–303.

at the end of the year 1599.* He was a member of a squadron of five ships which sailed in 1598 for the West Indies. The names of the ships, in German, as shown by an engraving on the title page of de Bry, were: "Hoffnung," "Glaube," "Liebe," "Trewe," "Frohlich Botschaft." The commanders of the fleet were: "Hoffnung," Admiral Jacob Mahu; pilot, William Adams; "Liebe," Vice-Admiral Simon de Cordes; "Glaube," G. van Benningen; "Trewe," J. van Bockholt; and "Frohlich Botschaft," Sebald de Weert. According to Burney, the "Hoffnung" and the "Liebe" eventually reached Japan, and the pilot, William Adams, was ordered by the Emperor to come to Osaca. He did so and the Emperor never would let him depart, and, after marrying a Japanese wife, Adams lived the remainder of his days in Japan.

Gerritz is mentioned several times in de Bry's narrative, in which his name is spelled Dirrick Gerritsz, and also Dierick Geeritsz. The account is in Latin, and is said to be a translation of the journal written in German by Ber-

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*Bry, Theodori de: "Americae. Nona & Postrema pars." Francof. Apud. Matth. Beckerum. 1602. The account of the expedition is a separate part of the book under the following title: "Vera et accurata descriptio eorum omnium, quae acciderunt quinque navibus Anno 1598, Amstredami expeditis & per fretum Magellanicum ad Moluccanas insulas perrecturis: naui praecipue Fidei, Capitano de VVeert addicta qui post infinitos labores & aerumnas biennio integro tolerates, tandem anno 1600. re infecta ad suos rediit."

Herrera, Antoine de: "Description des Indes Occidentales, qu'on appelle aujourdhuy le Nouveau Monde," par Antoine de Herrera, Grand Chroniqueur des Indes et Chroniqueur de Castille, Translatée d'Espagnol en Francais. A Amsterdam, chez Michel Colin, Anno MDCXXII. In this is "Recueil des Navigations de l'Estroit de Magellan," pages 179–195, in which is: "Voyages de cinq bateaux de Jaques Mahu et Simon de Cordes, qui partirent de Rotterdam, l'an 1598, pour l'Estroit de Magellan," pages 189–193.

Herrera, Antonio de: "Novus Orbis, Sive Descriptio Indiæ Occidentalis." Amstelodami, Apud Michaelem Bibliopolam, MDCXXII.

Brosses, Charles de: "Histoire des Navigations aux Terres Australes." A Paris, chez Durand, MDCCLVI. This includes the voyage of "Simon de Cordes et Sebald de Weert." "En Magellanique." Tome Premier, pages 274–294.

Burney: "A Chronological History," etc. London, 1806. In Part II, Chapter XII, pages 186–204, is "Voyage of Five Ships of Rotterdam, under the command of Jacob Mahu and Simon de Cordes, to the South Sea."

nard Jansz, surgeon of the expedition. No mention appears to be made by de Bry of antarctic discoveries, which may be accounted for by the fact that the author of the narrative was on one of the other ships, and that the narrative was published probably before news of Gerritz's discovery reached Europe.

The fleet sailed from Goree Harbor, Holland, on the 27th of June, 1598. The General or Admiral, Jaques Mahu, died on the 24th or 27th of September. This caused some changes among the commanders. Sebald de Weert became commander of the "Glaube," and Dirk Gerritz commander of the "Blyde Boodshap." The fleet entered the Strait of "Magalhaens"* on April 6, 1599, and spent most of the winter in *la Baye Verte*† or Cordes Bay,‡ "where they were miserably lodged."§ On the 2d of September the ships reached the South Sea, and on the 8th or the 10th or the 15th of September, either on account of fog,‖ on account of a furious storm,¶ or through some mistake in signalling,** the ships parted company.

Of the subsequent adventures of Gerritz, Herrera says, in 1622:†† "La Fuste de Diric Gherrits qui s'estoit esgaree le 15 Septembre des autres, scavoir de VVeert & Cordes, fut portee par la tempeste jusques' á 64 degrés au Sud de l'Estroit: ou ils descouvrivent un haut pays avec des montagnes pleines de neige a la facon du pays de Norvveghen: d'icy ils firent voile vers Chile en intention d'aller trouver leurs compagnons en l'ile de S. Marie: Mais ils furent portés par fortune au port de S. Iago de Valparayso; ou ils furent accablés des ennemis."

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* I quite agree with Captain James Burney ("A Chronological History," etc., Vol. I, page 13) in thinking it a "strange practice" to translate and alter proper names. The name of Magalhaens should be restored to the strait which he first sailed through.

† Herrera.

‡ Burney.

§ Herrera.

‖ Herrera.

¶ De Brosses.

** Burney.

†† Page 193 (French); Fol. 80 (Latin).

Herrera's Latin version says: "Liburnica que Theodorum Gerardi vehebat, tempestatum vi versus Austrum propulsa fuit ad gradus usque 64. in qua altitudine posita ad Australem plagam solum monto sum & nivibus opertum eminus conspexit, qualis Norvvegiæ esse solet facies. Versus insulas Salomonis exporrigi videbatur. Hinc Chilam petijt & ab insula S Mariæ quo loci socios se repertutum putabat, aberrans, in portum S. Jacobi de val Parayso se recepit & cum humanitatis ac benevolentiæ officia omnia negarent indigenæ, itinere longo confectis vectoribus & commeatus indiga, in hostium manus se dedit."

De Brosses' account in 1756 is as follows: * "La même tempête qui avoit fait perdre la flotte aux deux précédents, dispersa de même les trois autres navires. Elle jetta Theodoric de Gueritk jusqu'a 64° de latitude australe. On ne nous dit pas la longitude qui serait très-nécessaire a scavoir: car peut-etre personne n'a jamais été si loin vers l'antarctique. Il y découvrit une côte d'un aspect semblable a celle de Norwege, monstueuse, couverte de neige, s'étendant, à ce qu'il paroissoit, du côté des isles Salomon. Il revint aux côtes du Chili. * * *"

Burney's account in 1806 is the following: † "The yacht commanded by Dirck Gherritz was separated from all the other ships, and was carried by tempestuous weather to the south of the *Strait*, to 64° south latitude, where they discovered a high country, with mountains, which were covered with snow like the land of Norway. Gherritz afterwards sailed to the coast of Chili, in hopes that he should there rejoin some of the fleet; but he missed the Island Santa Maria, and was taken by the Spaniards at Valparaiso.

"The lands ‡ discovered in this voyage have no place assigned them in any of the charts now extant; and as they were omitted in the charts to De Bry's collection, it is not probable that they were ever marked on any.

"The islands seen in 16° north, in the Pacific Ocean, may be conjectured to be the same which appear in the

* Page 290.
† Page 198.
‡ Page 204.

Spanish charts with the name of Gaspar Rico, but no use can be made of the description which Adams has given of them. Neither can the land seen by Captain Dirk Gherritz in 64° south be laid down from the account given; but a short notice of Gherritz land ought to be inserted on the charts, near the situation, which may be supposed to be about 5° to the west of the meridian of the western entrance of the Strait of Magalhanes, where there is room for such notice or remark, perfectly free from interference with other lands, or with any other necessary information."

Gerritz was the first navigator who positively saw land in Antarctica, and therefore he should be commemorated by having his name affixed to the place which he sighted. Two Englishmen, John Barrow, F.R.S., and Vice President of the Royal Geographical Society in 1831,* and Dr. Webster, of the "Chanticleer,"† wrote to that effect. While we can never expect to know exactly what spot Gerritz reached, the probability is that it was some of the western Shetlands, and some of the islands west of Gerlache Strait. Under the circumstances, it seems as if the proper thing to do would be to name the archipelago west of Gerlache Strait after Gerritz, and this is perhaps most just; or else call the entire land mass south of South America, Gerritz Land, or Gerritz Archipelago, as the Germans are doing.

The discovery of Gerritz appears to have been forgotten, or rather it was not noticed at the time, and we next find Pedro Fernandez de Queros seeking for a *Tierra Austral* in 1605. His able second in command, Luis Vaez de Torres, in 1606, sighted an extended coast south of New Guinea. The same land was sighted also the same year by a Dutch vessel. In 1616, Theodoric Hertoge, in the "Eendracht," also sighted another part of this land,‡ and the voyage of Abel Tasman may be looked on as the last step in the discovery of the land, which was at first supposed to be the

* *The Journal of the Royal Geographical Society of London* for MDCCCXXX-XXXI; London, MDCCCXXXI, page 62.

† "Narrative of a Voyage," etc., Vol. I, page 136.

‡ Burney: "A Chronological History," etc., Vol. II, pages 272, 313, 456.

one sought for, and which eventually received the name of Australia.

The belief that Tierra del Fuego extended without interruption to the regions of eternal ice was settled by the voyage round the world of the Dutchmen, Le Maire and Schouten, in 1616, when they sailed round South America and christened Cape "Hoorn."* Although not properly an antarctic voyage, yet it must be looked on as important as the first one narrowing the limits of a *Terra Australis Incognita.*

In 1643 Hendrick Brouwer's squadron sailed around Staaten Land, because the wind was unfavorable to pass Strait Le Maire.† This voyage also tended to a narrowing of the limits of a *Terra Australis Incognita.*

In 1675 Antonio de la Roché,‡ an English merchant, on a return voyage from Peru, was unable, on account of high winds and currents, to go through the Strait of "Magalhaens," or Strait Le Maire. He was driven out to sea eastward of Staaten Land, and in April, 1675, discovered a coast or one or more islands, probably those sighted by the "Leon" in 1756, and called South Georgia by Captain Cook.

Some of the Buccaneers also,§ at the end of the seventeenth and the beginning of the eighteenth centuries, reached some rather high southern latitudes. Bartholomew Sharp reached 58° 30′ south latitude, in 1681; Woode Rogers, 62° south latitude, in 1709; La Barbinais, 61° 30′ south latitude, in 1714; George Shelvocke, 61° 30′ south

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*Herrera: "Description des Indes Occidentales," etc., Amsterdam, MDCXXII, contains "Journal & Miroir de la Navigation Australe du vaillant bien renommé Seigneur Jaques Le Maire;" Chef et conducteur de deux navires Concorde et Horne; pages 105–174.

Burney: "A Chronological History," etc., Vol. II, pages 354–452.

† Burney: "A Chronological History," etc., Vol. III, pages 115, 145.

‡ Burney: "A Chronological History," etc., Vol. III, pages 395–404. Burney's is the best account in English of this voyage. He drew his materials from Francisco de Seixas y Lovera's "Descripcion Geographica de la Region Magallanica."

§ De Brosses: "Histoire des Navigations aux Terres Australes," Vol II. Burney: "A Chronological History," etc., Vol. IV.

latitude, in 1719; and Roggewin, 62° 30′ south latitude, in 1721.

In 1738–39, Lozier Bouvet, a French sea officer,* made a search for the lands discovered by the Sieur de Gonneville in 1503, which were supposed to lie south of the Cape of Good Hope.† Bouvet commanded the frigate "l'Aigle" and M. Hays the frigate "la Marie." In 49° south latitude they saw three great ice islands. On January 1, 1739, Bouvet discovered a high land covered with snow, to which he gave the name of *Cap de la Circoncision*, in memory of the day. He presented twenty *piastres* to the principal pilot of the "Aigle," who had first sighted the land. Bouvet describes it as in 54° south latitude, and 27° or 28° longitude (Paris), and as stretching from northwest to southeast, for about 8 or 10 leagues on one side and 6 on the other. The two ships beat about here for twelve days, but were never able to get close to the coast nor even to land their boats on account of the ice, the fog and the adverse winds. Then they sailed eastward in about 57° south latitude, for 425 leagues, until January 25th, always along the pack and constantly seeing whales and "sea wolves." Bouvet then went north in search of the place where Gonneville landed.

In 1756 the Spanish ship "Leon" sailed from Valparaiso for Europe, and after passing Cape Hoorn, unfavorable winds drove her eastward.‡ On June 28th, when at least 125 leagues east of the Falkland Islands, land was sighted, to the great surprise of the navigators, in 55° 10′ south latitude. The next day it was found to be a coast at least 25 leagues long, with sharp and craggy mountains. It was called the Isle de San Pedro. There is no doubt that it is the land since called South Georgia.

Captain Marion du Fresne and the Chevalier Ducles-

* De Brosses: "Histoire des Navigations aux Terres Australes," Vol. II, pages 255–259.

† It has been suggested that de Gonneville reached Madagascar, also Australia. See Burney: "A Chronological History," etc., Vol. I, pages 377–379.

‡ Burney: "A Chronological History," etc., Vol. V, pages 136–142.

meur, in the "Mascarin" and the "Marquis de Castries,"* discovered, in January, 1772, some small islands in between 46° and 47° south latitude, and about 50° 30′ to 53° east longitude. They christened them Terre d' Espérance, Ile de la Caverne, Iles Froide, and Ile Aride, but they are now known as the Crozet Islands.

Captain Yves J. de Kerguelen,† also a Frenchman, discovered, on February 12 and 13, 1772, another southern island in 49° south latitude, 69° east longitude, which has since, in memory of its discoverer, received the name of Kerguelen Island. The shores were alive with antarctic animals and birds, so that the island may perhaps be considered as an outlier of Antarctica.

Lieut. James Cook, R.N., on a voyage round the world in the ship "Endeavour," went just beyond 60° south latitude, between 74° and 75° west longitude, on January 30, 1769. When approaching New Zealand, on October 7, 1769, he wrote: "This land became the subject of much eager conversation; but the general opinion seemed to be that we had found the *Terra Australis Incognita*." ‡

Lieutenant Low states that an English geographer, Alexander Dalrymple, published a paper about 1770, asserting the existence of an antarctic continent extending north of 60° south latitude, and that Captain Cook searched for this on his second voyage round the world. Captain Cook commanded the "Resolution," and Captain Furneaux commanded the "Adventure." § At the Cape of Good Hope they found the Swedish naturalist, Dr. André Sparrman, and

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* "Nouveau Voyage à la Mer du Sud," commencé sous les ordres de M. Marion * * * et achevé * * * sous ceux de M. le Chevalier Duclesmeur * * * d'après les Plans et Journaux de M. Crozet. Paris, chez Barrois l'aîné, MDCCLXXXIII.

† Kerguelen, M. de: "Relation de deux voyages dans les mers Australes et des Indes," faits en 1771, 1772, 1773 et 1774. A Paris, chez Knapen & Fils, MDCCLXXXII; pages 21–24.

‡ Hawkesworth, John: "An Account of the Voyages Undertaken by the Order of His Present Majesty for Making Discoveries in the Southern Hemisphere." London. MDCCLXXIII.

§ Cook, James: "A Voyage Towards the South Pole and Round the World," performed in His Majesty's Ships the "Resolution" and "Adventure,"

invited him to join the expedition. From the Cape, Cook proceeded south and east, and on January 17, 1773, crossed the Antarctic Circle in 39° 35′ east longitude, and reached 67° 15′ south latitude. Here he was stopped by a pack composed of field ice, with thirty-eight ice islands in sight. He turned northward and later southward. On the 23d of February he reached 61° 52′ south latitude, 95° 2′ east longitude. Here there were so many ice islands that he gave up attempting to cross the Antarctic Circle, and continued on an easterly course until, on March 17, he reached 59° 7′ south latitude, 146° 53′ east longitude, when he bore away north.

In December, 1773, Cook again went south, and on December 22d reached 67° 31′ south latitude, 142° 54′ west longitude, where he was stopped by the pack. On January 30, 1774, he reached 71° 10′ south latitude, 106°54′ west longitude, where a great ice field, in which ninety-seven ice hills were in sight, blocked further progress. He then went in search of the *Terra Australis Incognita* that Juan Fernandez was said to have discovered.

In January, 1775, Captain Cook went south from Staaten Land, on a search for La Roché's Island. On January 14, in 53° 56′ south latitude, 39° 24′ west longitude, he sighted land, which is undoubtedly the one discovered, perhaps by Amerigo Vespucci, certainly by La Roché, and which was seen by the Spanish ship "Leon." It lies between 53° 57′ and 54° 57′ south latitude, and 38° 13′ and 35° 34′ west longitude. Cook spent several days there and renamed it the Isle of Georgia. He then stood eastward again, and on

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in the years 1772, 1773, 1774 and 1775. Second edition, London, W. Strahan & T. Cadell, MDCCLXXVII.

"Journal of the 'Resolution's' Voyage," in 1772, 1773, 1774 and 1775, on discovery of the Southern Hemisphere, by which the non-existence of an undiscovered continent, between the equator and the fiftieth degree of southern latitude, is demonstrably proved. Also a "Journal of the 'Adventure's' Voyage," in the years 1772, 1773 and 1774. Dublin, Caleb Jenkin, MDCCLXXVI.

Low, Lieut. Charles R. (H. M. Indian Navy): "Captain Cook's Three Voyages Round the World." London, George Routledge & Sons.

Sparrman, Dr. André: "Voyage au Cap de Bonne Espérance et Autour du Monde, avec le Captaine Cook." Paris, chez Buisson, MDCCLXXXVII.

January 31st sighted land in 59° south latitude, 27° west longitude, and on the same day another coast in 59° 13′ south latitude, 27° 45′ west longitude, which was named Southern Thule. On February 1st he sighted Cape Montagu, and on the 3d, in 57° 11′ south latitude, 27° 6′ west longitude, two islands, which he called the Candlemas Isles. After a vain search for Bouvet Island, he returned to the Cape.

This voyage of Cook was important, because it was the first one to circumnavigate Antarctica, and to circumscribe its limits; and also because it did away with the belief in a *Terra Australis Incognita* north of 60° south latitude.

II. VOYAGES UP TO THE DISCOVERY OF A SOUTH POLAR CONTINENT.

During the following six decades many of the discoveries in Antarctica were made by whalers or sealers, men who went out for commercial and not for scientific purposes. Some of them penetrated a good distance south, and in so doing made some important discoveries. Although their voyages added to geographical knowledge, yet about no travels is it more difficult to get information, as the discoveries in many cases seem to have been merely entered in the log books.

In 1794 the Spanish *corvette* "Atrevida" was sent to survey the Aurora Islands, which were discovered, it was said, in 1762, by the ship "Aurora."* In 1769 the ship "San Miguel" saw some islands, which it was suspected were the Auroras. In 1774 the ship "Aurora" again reported them. Three other vessels, the "Pearl" in 1779, and the "Dolores" and the "Princess" in 1790, also are said to have seen these islands. The "Atrevida" went purposely to situate them, and reported that the islands were three in number; and that the southernmost was in 53° 15′ south

* This account is compiled from Captain James Weddell's "A Voyage Towards the South Pole," pages 61–67, in which Weddell quotes the publications of the Royal Hydrographical Society of Madrid, 1809, *Memoria Segunda*, tomo 1°, pages 51, 52, and appendix to same, Vol. I, page 213, No. IV.

latitude, 47° 57′ west longitude; the second in 53° 2′ south latitude, 47° 55′ west longitude; and the third in 52° 37′ south latitude, 47° 43′ west longitude. The Spanish officers, however, said that none of the circumstances connected with the islands which they saw agreed with those reported of the Auroras.*

The earliest discovery by an American sealer appears to be the following: † "Swain's Island, latitude 59° 30′ south, longitude 100° west by calculation, discovered by Captain Swain, of Nantucket, in 1800. Resorted to by many seals."

In 1808 Bouvet Island was seen by two English whaling vessels,‡ the "Snow Swan," Mr. James Lindsay, master, and the "Otter," Mr. James Hopper, master. The "Swan" sighted Bouvet Island on October 6, 1808, and the "Otter" on October 10, 1808. They recognized the *Cap de la Circoncision*, but could not land, on account of fogs and ice. The island was determined to be in 54° 15′ south latitude, 4° 15′ east longitude.

In the spring of the year 1812, Mr. Edmund Fanning § was appointed commander of an American discovery expedition, to consist of the ships "Volunteer" and "Hope," intended for the exploration of the Southern Hemisphere and a voyage round the world. The expedition was on the point of sailing when, owing to the breaking out of war, it was given up. About this time, however, it is barely possible that Gerritz Land was rediscovered. Dr. Fricker ‖ says: "At all events, probability points that way, and it is certain that the English hydrographer, James Horsburgh, told the German geographer, Heinrich Berghaus, that the

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* See *post*.

† Fanning, Edmund: "Voyages Round the World; with Selected Sketches of Voyages to the South Seas, North and South Pacific Oceans, China," etc., between the years 1792 and 1832. New York, Collins & Hannay, MDCCCXXXIII, page 447.

‡ Burney: "A Chronological History," etc., Vol. V, pages 35–37.

§ "Voyages," etc., pages 492–494.

"Executive Documents," 26th Congress, 1st Session, 1839–40, Vol. II, Doc. No. 57: "Memorial of Edmund Fanning."

‖ Fricker, Dr. Karl: "The Antarctic Regions," London and New York, 1900, page 47. A translation of "Antarktis, Bibliothek der Länderkunde," Berlin, Schall & Grund, 1898.

island group had been a station for American seal hunters since 1812. The motive for keeping its existence secret was the desire to retain the sole use of the station for their own profit." It would seem probable that Mr. Horsburgh's information was incorrect, since Fanning says nothing of the matter. Still, further evidence may yet be found.

Mr. William Smith,* master of the brig "Williams," of Blythe, took an unusually southerly course round Cape Hoorn in February, 1819. Apparently by accident, on February 19th, he sighted some islands in 62° 17′ south latitude, 60° 12′ west longitude. On October 15th following he sighted the same islands, and this time examined them more carefully, christening several of them and calling the whole group New South Shetland. He thought he could distinguish through the telescope trees similar to the Norway pine. Mr. Smith appears to have gathered the impression that the Shetlands were a more or less connected mass of land, and in fact he speaks of some of them as the mainland, which appears to be the first hint, since the time of Captain Cook, that there was anything more than small islands in the Antarctic. His chart, however, shows that he was always north of the Shetlands.

Captain James P. Sheffield † and Supercargo William A. Fanning sailed in the brig "Hersilia," of Stonington, in July, 1819, on an exploring and sealing voyage, due to the initiative of Mr. Edmund Fanning, who had read the account of Gerritz's discovery of land at the south of Cape Hoorn, and had also been at South Georgia at the breaking up of the winter ice and noticed that ice islands came floating there after gales from the W. S. W.; he believed, therefore, that there was land in that quarter, and this was the inducement for the search. On the return of the "Hersilia," Sheffield and Fanning reported that they had seen

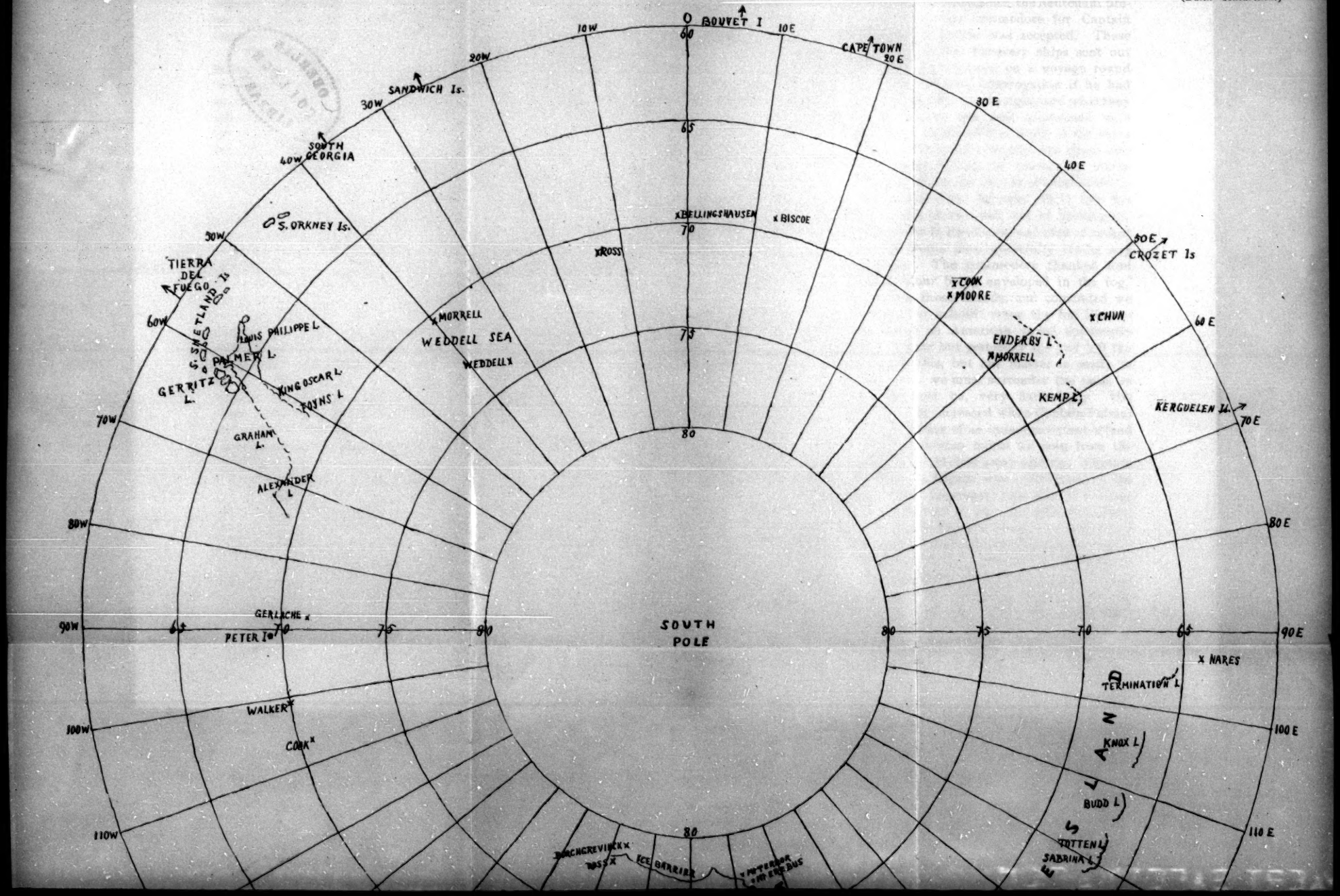
* The *Edinburgh Philosophical Journal*, Vol. III, Edinburgh, 1820, pages 367–380, Art. XXI: "Account of the Discovery of New South Shetland, with Observations on its Importance from a Geographical, Commercial and Political Point of View, with Two Plates;" by Mr. J. Miers. Communicated by Mr. Hodgskin.

† Fanning, Edmund: "Voyages Round the World," etc., pages 428–434.

the Aurora Islands, and then proceeded south, and that in about 63° south latitude, in February, 1820, they had found several islands. One they called Mount Pisgah Island, others Fanning's Islands, and another Ragged Island, on which they effected a landing at Hersilia Cove, the second recorded landing in Antarctica. They did not rename the group, believing it was Gerritz Land. They captured many seals, and this voyage was the forerunner of those which resulted in the extermination of the Antarctic fur seal.

Mr. Edward Bransfield, R.N.,* sailed from Valparaiso on December 20, 1819, in the brig "Williams," to examine Mr. Smith's newly found islands. He reached the Shetlands on January 16, 1820, in 62° 26′ south latitude, 60° 54′ west longitude. Three days afterwards, about 2° more to the eastward, he anchored in an extensive bay and was able to land, apparently the first time any one did so in Antarctica. He found also some stunted grass, and this seems to be the first time vegetation was noticed in Antarctica. Like Mr. Smith, Bransfield appears to have considered the Shetlands as a more or less connected mass of land, for Dr. Slaney's involved account speaks of them as a line of coast which "appeared high, bold and rugged." He says further that the land was traced 9° or 10° east and about 3° north and south, and that they could not ascertain whether it was part of a continent or only a group of islands. "If it is insular, there must be *some* of an immense extent, as we found a gulf nearly 150 miles in depth, out of which we had some difficulty in finding our way back again." According to the English Admiralty charts, Bransfield's course must have been north of the Shetlands, then eastward, then southward, along about the meridian of 52° 30′ west longitude, to about 64° 30′ south latitude, and this cruise is probably what Dr. Slaney refers to as a "gulf." Bransfield may have sighted Joinville Island.

* The *Edinburgh Philosophical Journal*, Vol. IV, Edinburgh, 1821, pages 345–348, Art. XVII: "Notice of the Voyage of Edward Bransfield, Master of His Majesty's Ship 'Andromache,' to New South Shetland." [By Dr. H. M. S. Slaney.]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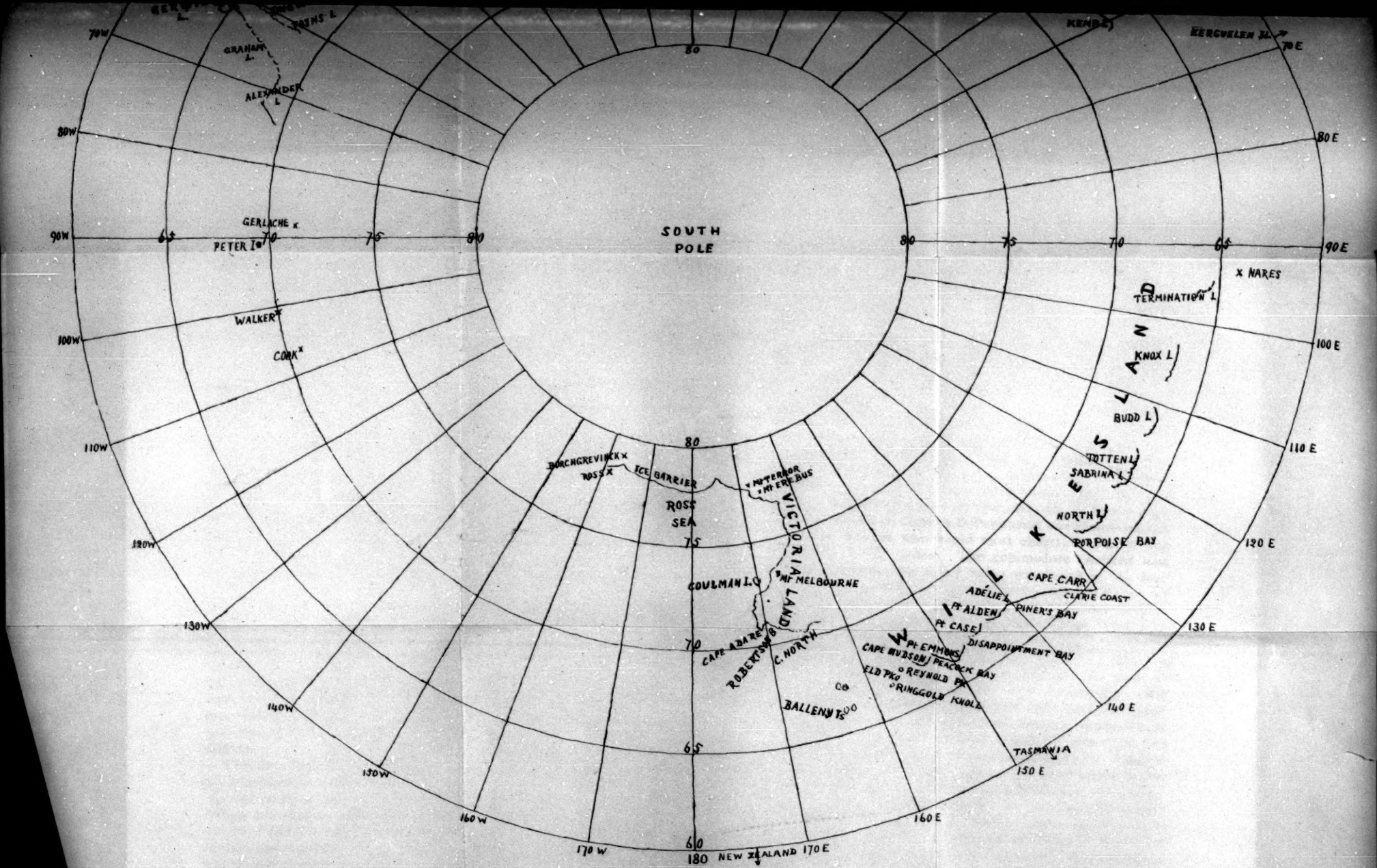

SKETCH CHART OF ANTARCTICA,
Drawn by Edwin Swift Balch, March, 1901.

Captain Nathaniel B. Palmer, an American sealing captain, comes next in chronological order; and I quote his first two voyages in full, because of their importance in the history of Antarctic discovery.*

"The next season after the 'Hersilia's' return from the South Shetlands, a fleet of vessels, consisting of the brig 'Frederick,' Captain Benjamin Pendleton the senior commander, the brig 'Hersilia,' Captain James P. Sheffield; schooners 'Express,' Captain E. Williams, 'Free Gift,' Captain F. Dunbar, and sloop 'Hero,' Captain N. B. Palmer, was fitted out at Stonington, Connecticut, on a voyage to the South Shetlands. From Captain Pendleton's report, as rendered on their return, it appeared that while the fleet lay at anchor in Yankee Harbor, Deception Island, during the season of 1820 and 21, being on the lookout from an elevated station on the mountain of the island during a very clear day, he had discovered mountains (one a volcano in operation) in the south; this was what is now known by the name of Palmer's Land; from the statement it will be perceived how this name came deservedly to be given to it, and by which it is now current in the modern charts. To examine this newly discovered land, Captain N. B. Palmer, in the sloop 'Hero,' a vessel but little rising 40 tons, was despatched; he found it to be an extensive mountainous country, more sterile and dismal, if possible, and more heavily loaded with ice and snow, than the South Shetlands; there were sea leopards on its shore, but no fur seals; the main part of its coast was ice bound, although it was in the midsummer of this hemisphere, and a landing consequently difficult.

"On the 'Hero's' return passage to Yankee Harbor she got becalmed in a thick fog between the South Shetlands and the newly discovered continent, but nearest the former. When this began to clear away, Captain Palmer was surprised to find his little barque between a frigate and sloop of war, and instantly run up the United States flag; the frigate and sloop of war then set the Russian colors. Soon

* Fanning, Edmund: "Voyages Round the World," etc., pages 434–440.

after this a boat was seen pulling from the commodore's ship for the 'Hero,' and when alongside, the lieutenant presented an invitation from his commodore for Captain P. to go on board: this of course was accepted. These ships he then found were the two discovery ships sent out by the Emperor Alexander of Russia, on a voyage round the world. To the commodore's interrogation if he had any knowledge of those islands then in sight, and what they were, Captain P. replied, he was well acquainted with them, and that they were the South Shetlands, at the same time making a tender of his services to pilot the ships into a good harbor at Deception Island, the nearest by, where water and refreshment such as the islands afforded could be obtained; he also informed the Russian officer that his vessel belonged to a fleet of five sail, out of Stonington, under command of Captain B. Pendleton, and then at anchor in Yankee Harbor, who would most cheerfully render any assistance in his power. The commodore thanked him kindly; 'but previous to our being enveloped in the fog,' said he, 'we had sight of those islands, and concluded we had made a discovery; but behold! when the fog lifts, to my great surprise, here is an American vessel apparently in as fine order as if it were but yesterday she had left the United States; not only this, but her master is ready to pilot my vessels into port; we must surrender the palm to you Americans,' continued he, very flatteringly. His astonishment was yet more increased when Captain Palmer informed him of the existence of an immense extent of land to the south, whose mountains might be seen from the masthead when the fog should clear away entirely. Captain Palmer, while on board the frigate, was entertained in the most friendly manner, and the commodore was so forcibly struck with the circumstances of the case, that he named the coast then to the south Palmer's Land; by this name it is recorded on the recent Russian and English charts and maps which have been published since the return of these ships. The situation of the different vessels may be seen by the plate: they were, at the time of the lifting of the fog and its going off to the eastward, to the south, and in sight

of the Shetland Islands, but nearest to Deception Island. In their immediate neighborhood were many ice islands, some of greater and some of less dimensions, while far off to the south the icy tops of some two or three of the mountains on Palmer's Land could be faintly seen; the wind at the time was moderate, and both the ships and the little sloop were moving along under full sail.

"The following season, in 1821–22, Captain Pendleton was again at Yankee Harbor with the Stonington fleet: he then once more despatched Captain Palmer in the sloop 'James Monroe,' an excellent vessel of upwards of 80 tons, well calculated for such duties, and by her great strength well able to venture in the midst of and wrestle with the ice. Captain Palmer reported on his return that, after proceeding to the southward, he met ice fast and firmly attached to the shore of Palmer's Land; he then traced the coast to the eastward, keeping as near the shore as the ice would suffer; at times he was able to come along shore, at other points he could not approach within from one to several miles, owing to the firm ices, although it was in December and January, the middle summer months in this hemisphere. In this way he coasted along this continent upwards of fifteen degrees, viz., from 64 and odd, down below the 49th of west longitude. The coast, as he proceeded to the eastward, became more clear of ice, so that he was able to trace the shore better; in 61° 41′ south latitude, a strait was discovered, which he named Washington Strait; this he entered, and about a league within came to a fine bay, which he named Monroe Bay; at the head of this was a good harbor; here they anchored, calling it Palmer's Harbor. The captain landed on the beach among a number of those beautiful amphibious animals, the spotted glossy-looking sea leopard, and that rich golden-colored noble bird, the king penguin; making their way through these, the captain and party traversed the coast and country for some distance around, without discovering the least appearance of vegetation excepting the winter moss. The sea leopards were the only animals found; there were, however, vast numbers of birds, several different species of the pen-

guin, Port Egmont hens, white pigeons, a variety of gulls, and many kinds of oceanic birds; the valleys and gulleys were mainly filled with those never dissolved icebergs, their square and perpendicular fronts several hundred feet in height, glistening most splendidly in a variety of colors as the sun shone upon them. The mountains on the coast, as well as those to all appearance in the interior, were generally covered with snow, except when their black peaks were seen here and there peeping out."

Captain Palmer made numerous other voyages, some of which appear to be unrecorded. He certainly made one in 1828–29, for he is mentioned by Dr. Webster, of the "Chanticleer." In 1829–30, Captain B. Pendleton and Captain Palmer,* in the brigs "Seraph" and "Annawan," made a cruise north and west of Palmer Land. Some scientists went on this expedition, among whom were Messrs. J. N. Reynolds and Watson. Mr. Reynolds† afterwards took a leading part in the formation and start of the United States Exploring Expedition, and in urging Congress in 1836 to send the latter, he said, among other things:‡ "It was in company with this same Captain Palmer, during my late voyage to the South Seas, that I visited the whole of this extensive group of islands lying north of the coast of

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*Fanning, Edmund: "Voyages Round the World," etc., pages 478–491. Fanning may have had more knowledge than is apparent from his book of the extent of the western mainland, for on page 476 he says: "but from the information the author has in his possession, it is presumed that the continent of Palmer's Land does not extend further west than to the one hundredth degree of west longitude." This is, probably, the only authoritative hint of the existence of the South Polar Continent before the discovery by Wilkes. Fanning wished to have the Antarctic explored scientifically, and urged the matter in a paper: "Memorial of Edmund Fanning; To illustrate the views in a petition presented to Congress, praying that a national discovery and exploring expedition be sent to the South Seas," etc., December 18, 1833; 23d Congress, 1st Session. Referred to the Committee on Naval Affairs and ordered to be printed.

†"Address on the Subject of a Surveying and Exploring Expedition to the Pacific Ocean and South Seas." Delivered in the Hall of Representatives on the evening of April 3, 1836, by J. N. Reynolds. New York, Harper & Brothers, 1836.

‡Address, etc., page 34.

Palmer's Land, the extent of which neither we nor any subsequent navigators have as yet ascertained; though a British vessel touched at a single spot in 1831, taking from it the American and giving it an English name." Mr. Reynolds also gave an almost identical account as that of Fanning of the meeting of the Russian commander and the American sealing captain, and of the naming of Palmer Land.

Dr. W. H. R. Webster,* of the "Chanticleer," has fortunately recorded his impressions of Palmer, for, thanks to him, we get a glimpse of the personality of the discoverer of Palmer Land. "Early on the following morning, Sunday, 25th October, Captain Foster left us, in quest of a harbour for the reception of the "Chanticleer," while the pendulum experiments were going forward. After examining New Year's Harbour, which he did not approve of, in his way along the coast he discovered an American schooner at anchor in one of the creeks: the name of the schooner was the "Penguin" of Stornington [*sic*]: and the reception he met with from Captain Palmer, who commanded her, was most kind. Captain Palmer immediately offered to conduct the "Chanticleer" into the creek, which he had named North Port Hatchett. When he made his appearance on board the brig with Captain Foster, we took him for another Robinson Crusoe in the shape of some shipwrecked mariner. He was a kind and good-hearted man; and thinking that they would be a treat to us, had brought with him a basket of albatross's eggs, which were to us a most acceptable present. How completely does this little incident, trifling as it may appear, prove the justness of Captain Hall's observations in his useful little work entitled 'Fragments of Voyages,' that it is the time and manner of making a present that gives it all its value. * * * On the following day, under the care of Captain Palmer, the "Chanticleer" was safely anchored in the beautiful little harbor of North Port Hatchett."

The account by Fanning of Palmer's first two voyages

* "Narrative of a Voyage," etc., Vol. I, pages 98–99.

proves several facts: (1) That the land discovered, visited and perhaps even landed on by Palmer is the western mainland of Antarctica; (2) that Palmer, therefore, possibly was the first to sight the mainland of Antarctica; (3) that as Palmer on his journey along the coast went eastward, he is, therefore, the first who coasted along the northern shore of the western mainland, possibly for its entire length; (4) that it is this northern coast which was called Palmer Land by the American sealers. It is the coast extending from Gerlache Strait on the west, to at least the point indicated in the statement of Admiral Wilkes:* "I place the eastern extremity of Palmer's Land, or Mount Hope, in longitude 57° 55′, W., latitude 63° 25′ S." This is Palmer Land, and the name ought to be restored to it.†

In 1819–21 a Russian expedition, under Captain F. G. Bellingshausen, in the "Vostok," and Captain Lazarew, in the "Mirny," circumnavigated Antarctica.‡ They left Kronstadt in 1819, and in December sailed along the south coast of South Georgia. On January 3 and 4, 1820, they discovered the Traversey Islands, in 56° 41′ south latitude, 28° 9′ west longitude. On the 8th they determined that the Candlemas Isles were small islands and not a coast. They then sailed south and east. On January 28th, Bellings-

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* "Narrative U. S. E. E.," Vol. I, page 136.

† Lieutenant de Gerlache, in his recent paper "Notes sur les Expéditions," etc., *Société Royale Belge de Géographie, Bulletin*, vingt quatrième Année, 1900, page 391, appears to hold this opinion. In the same article, at page 393, M. de Gerlache says: "During the years 1820, 1821 and 1822, seven ships were lost at the Shetlands, almost all during easterly storms. The men of one of these ships were obliged to winter on the coast; during many months they endured the greatest privations." This appears to be the first time any one wintered in Antarctica.

‡ Good short accounts of Bellingshausen's voyage are:

Bellingshausen: "Bibliothèque Universelle des Voyages," par M. Albert Montémont, Paris, MDCCCXXXIV, Tome XXI, pages 431–448.

Lowe, F.: "Bellingshausens Reise nach der Südsee und Entdeckungen im Südlichen Eismeer;" *Archiv für wissenschaftliche Kunde von Russland*, A. Erman, Berlin, 1842, Vol. II, pages 125–175. The narrative of Bellingshausen's voyage has been published in full only in Russian. Herr Lowe gives the title: "Dwukratnya isiskania w' Jujnom Ledowitom Okeanje i plawanie wokrug swjeta," etc., St. Petersburg, 1831. I have not seen this book.

hausen reached 69° 21′ south latitude, 2° 15′ west longitude, and on February 2d, 66° 25′ south latitude, 1° 11′ west longitude, at both of which positions he was stopped by the pack. He then steered eastward, and on February 17th reached 69° 6′ south latitude, and on the 19th, 68° 5′ south latitude, 16° 37′ east longitude. Later he reached 66° 53′ south latitude, 40° 56′ east longitude, where he thought land must be near, on account of the numbers of birds.

The following southern summer, Bellingshausen started from Sydney and sailed south and east. M. Montémont says: "On the 11th of January, 1821, we discovered, in 69° 30′ south latitude, an island, which we named in honor of the founder of our navy, Peter I. Island. The 17th of the same month we discovered a coast in the same latitude, to which, in honor of the sponsor of our journey, we gave the name of Alexander I. The lands are surrounded with ice, which prevented us from approaching them and examining them near by. The discovery of these two islands is moreover remarkable in that of all these lands they are the most southerly which have yet been discovered in this hemisphere." Herr Lowe says: "The sudden change in the color of the water led Captain Bellingshausen to believe that this [Alexander] land must be of considerable size." From here Bellingshausen sailed to the Shetlands, to which he gave Russian or Napoleonic names: Borodino, Smolensk, Leipzig, Waterloo (James Island), Mordwinow (Elephant Island), etc. He then returned home via the Orkneys and South Georgia.

Bellingshausen's voyage is important, for he narrowed considerably the unexplored regions of the South Pole, and crossed six times the Antarctic Circle, within which he sailed long distances. He may have been the first to sight the mainland of Antarctica by his discovery of Alexander Land.

[*To be continued.*]

ROTARY TRANSFORMERS:

THEIR HISTORY, THEORY AND CHARACTERISTICS.*

By George W. Colles, A.B., M.E.

(*Continued from p. 235.*)

MACHINES FOR ALTERNATING AND POLYPHASE CURRENTS.

What gave the great impulse to the further development and perfection of rotary current-transforming devices was, needless to say, the discovery of the properties of polyphase currents by Tesla and Ferraris and their publication in 1888. Without this discovery, electrical engineering progress would probably have been directed into continuous rather than alternating-current channels, as the simple alternating current is, in general, unsatisfactory for any purpose except lighting.

But the polyphase currents themselves were known for many years before that discovery; in fact, an old machine of Gramme is shown by Thompson,[28] which is adapted to produce simultaneously currents of four phases, in octature, operating in as many different circuits.

It is not surprising, therefore, that the first continuous-alternating current transformer which we shall have occasion to mention is in reality a four-phase machine, though not recognized by its author as such; nor that the first transformer for polyphase currents is the invention of Tesla.

Before proceeding to the consideration of machines with rotating parts, it will be well to consider what transformations can be made by stationary apparatus (already referred to on page 210),† and the nature of the apparatus.

The peculiar property of polyphase currents is their ability to produce a rotating constant magnetic field without any corresponding mechanical rotation of the parts of the machine. Hence, wherever in apparatus of this description a continuous is replaced by a polyphase current, we

* A thesis presented in candidature for the degree of Master of Science, in the Columbian University, May, 1900.

[28] "Dynamo Electric Machinery," 4th ed., p. 641.

† See March number of this *Journal*.

may dispense with the rotating parts, sliding connections, commutators, etc., which are necessary to the former. Herein lies their great advantage.

Hence, if we desire to transform one polyphase current into another, we may simply take our induction ring (or dynamotor armature), wind both sides appropriately for the respective polyphase circuits, connecting them directly thereto, and our apparatus is complete without any rotating parts or exciting magnetic fields. A machine of this sort is seen in *Fig. 1* of Plate XIV.[29] Here the primary coils *B B'* produce a rotating field in the core with free poles at opposite ends of a diameter, precisely the same as in the ring type of inductorium; and this in like manner induces similar polyphase currents in the secondary coils *C C'*. As the primary and secondary coils are independent, we may have any pressure ratio between them. Moreover, although in the machine shown both circuits are of the two-phase species, this is not necessary; it is only necessary that a rotating field of constant strength be induced in the core by the action of the primary circuit, which, as is well known, can be equally well produced by any number of phases; conversely, this rotating field may be made to induce a current of any *other* desired number of phases in the secondary winding by simply winding the latter in the appropriate manner. This gives us a *phase* transformation. We cannot, however, accomplish a frequency transformation by this method; for the frequency in both coils will be equal to the frequency of rotation of the magnetic field, multiplied by the number of free poles formed therein; and this is necessarily the same for both.

This simplest form of polyphase transformer has, therefore, this advantage not possessed by some more complex forms, that we can accomplish a phase transformation with perfect ease along with our pressure transformation; but it has the very considerable disadvantage of a so-called "open magnetic circuit," to wit, free poles at different points of the ring. We can partially overcome this defect

[29] From Tesla's patent, No. 381,970, of May 1, 1888.

Fig. 1.

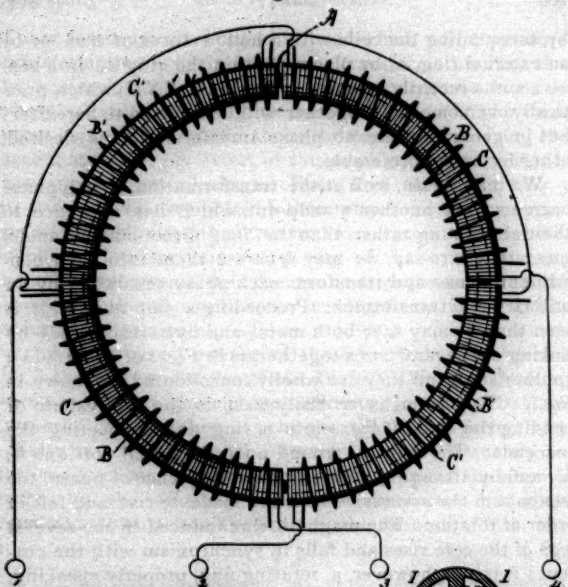

Fig. 2.

Fig. 3.

Fig. 4.

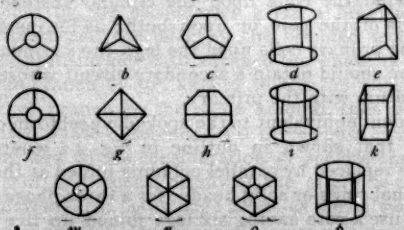

PLATE XIV.—Polyphase transformation. *Fig. 1*, Tesla's ring transformer. 1888. *Figs. 2–4*, core-shapes for polyphase transformers.

by surrounding the coils with a hollow torus of iron, or by an external ring, or by placing within the ring an iron center; and a recently invented form (Plate XXII) which practically overcomes it altogether will be referred to hereafter; but in general, where no phase transformation is desired, other forms are preferable.

We may, again, look at the transformation of polyphase currents from another standpoint, which has reference to their alternating rather than to their direct current analogies; that is to say, we may separate them into their constituent phases and transform each phase separately by an ordinary *A C* transformer. Proceeding a step further, it is seen that we may save both metal and hysteresis losses by linking our several cores together, as in *Fig. 2* of Plate XIV; another step, and they are wholly consolidated, as shown in *Fig. 3*. This form, as is easily seen, is the equivalent of bending the core of *Fig. 2* into a ring and connecting the two ends. The coils are wound upon the radial portions *K*, *K*; and by arranging them in proper sequence of phase, the currents in the successive coils are made to rise and fall in order of rotation. The magnetic flux induced in the several legs of the core rises and falls in synchronism with the current; it is not, however, a rotating flux, properly speaking, as in the ring transformer, but a polyphase—in this case a four-phase (or two-phase) flux; for no free poles exist at any time around the ring, and the flux merely shifts from one leg of the core to the next in order. We may, moreover, if desired, wind the coils upon the circular instead of the radial parts of the core, or upon both; as for instance, by placing the primary coils upon the legs, the secondary upon the rim, we should obtain a secondary circuit whose phases are in octature with the primary.

An evident equivalent to the spoked-wheel form of transformer is that shown in outline in *Fig. 4 i*, wherein the spokes are replaced by parallel columns joined at their ends by two equal rings or solid heads; for a three-phase current we might use a core having six legs joined up like a tetrahedron (*Fig. 4 b*); and many other forms readily suggest themselves, a variety of which are exemplified in *Fig. 4*.

These forms are intended to be used where only a pressure transformation is desired; a phase transformation may also be accomplished, as, for instance, from two-phase to three-phase current, by adding to the four legs of *Fig. 3* three other legs equally spaced about the center and carrying the secondary coils. A defect of this arrangement, however, is too large magnetic leakage. Even from the core of *Fig. 3* as it stands we may obtain a three-phase current by appropriately distributing the three secondary-circuit cells equably about the four sections of the ring of the core. Such an arrangement resembles in theory the arrangement for phase-transformation shown in some recent patents, which will be referred to later on.

A special case, however, of these methods just referred to, is the invention of Scott[30] (see Plate XV) for transforming two-phase into three-phase currents, and may be here noticed. This method has the great merits of perfect simplicity and high efficiency. Two ordinary *A C* transformers are used, whose primaries may have an equal number of turns, but the secondary coil of one transformer has a less number of turns than the other in the ratio of

$$\frac{\sqrt{3}}{2},$$

while the second has a lead attached to the center of its secondary which is connected, as shown, to one end of the secondary of the first-named coil. The primaries are placed across the respective mains of the two-phase circuit. The arrangement of the secondaries gives a branched or Y-shaped circuit, and the effect of the bisected secondary of the second transformer is to advance the phase of the current in one branch by 30°, and to retard the phase of that in the other branch by the same amount, thus producing the required phase difference for a three-phase circuit.

Passing now to the consideration of species transformation, we will first speak briefly of the alternate-polyphase transformation—No. (4) on page 209*—as the only one which

[30] Patent No. 521,051, of June 5, 1894.
* March number of this *Journal*.

can be accomplished by stationary means, and for this very reason one of the most important. The transformation from polyphase to alternating currents presents, of course, no difficulty. It is when we attempt to reverse the opera-

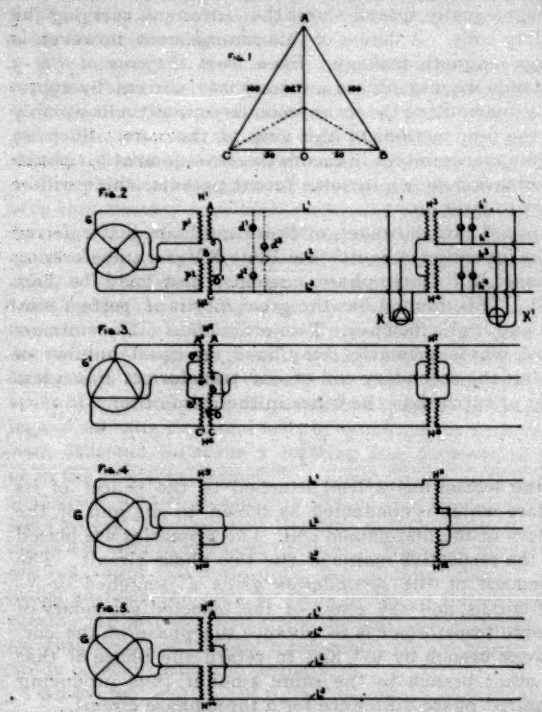

PLATE XV.—Scott's method of phase transformation. 1894.

tion, and produce a polyphase from an alternating current, that we are confronted with a serious practical problem. The case is precisely analogous to the mechanical one of converting rotary into reciprocating, and reciprocating into

rotary motion. For the first, a crank-and-pitman connection is all that is necessary. For the second, we need in addition a *fly-wheel* to store up energy at certain parts of the revolution, and give it up again at the dead points, during which no energy is imparted to the rotating shaft. Just so it is in the parallel electrical case; for, since the energy imparted by the alternating current is periodically at zero, while the polyphase energy flow is constant, some energy must be stored up in the transforming apparatus during the maxima, to be given out at the zero points.

This energy may be stored either electrically or mechanically. Not that these two include all the possibilities, but these are means ready to hand, and the only ones which have so far been employed. As mechanical means we have, of course, the fly-wheel or momentum of moving parts—which implies, of course, a machine with moving parts. As electrical means we have two: the induction coil and the condenser; the first of which stores the energy electromagnetically, in an electromagnetic field of force, the second electrostatically, in an electrostatic field of force; the first in producing a lagging, the second a leading current. We may therefore, it is clear, by dividing a monophase circuit into two branches, and introducing inductance into one, and capacity into the other, produce in the two branches the phase-difference appropriate to a two-phase, three-phase, or in general, any desired polyphase circuit. This, then, sums up the means so far known to us for transforming alternating into polyphase currents without the use of a transformer; and all such transformers hitherto made are based on these means.

The disadvantages of such a mode of transformation are considerable. In the first place the efficiency of the transformation is low, due principally to the absorption of energy by hysteresis in the reactance coil, which, as calculated by Professor Fessenden,[31] has an efficiency as an accumulator of energy not greater than 75 per cent.; whereas that of a fly-wheel is practically 100 per cent.; so that, all

[31] Fessenden, in *Elec. World*, V. 26, p. 618.

things considered, the highest theoretical efficiency of conversion of such an apparatus is about 91⅛ per cent.; which, as he justly remarks, is not satisfactory. In the second place, condensers of sufficient capacity for this work, in which the frequency is generally low, are expensive, and not always reliable. Thirdly, the regulation is bad, due to the interdependence of the two circuits. These several defects combine to render the use of a rotary transformer preferable in many or most cases, where such transformation is necessary, particularly on a large scale; on the other hand, for small isolated motors, and particularly for starting motors of the synchronous alternating type, such means are very useful.

Bradley[22] has devised a transformer, described by him before the American Institute of Electrical Engineers, in which he uses a condenser to produce a leading branch-current in the high-voltage primary, and winds this and the original current on transforming coils so as to produce in low-voltage secondary wires a three-phase current, in the same manner as the Scott *2 P C–3 P C* transformer described above (page 267). The three-phase secondary current, however, is properly adjusted as to its phase-differences only at full load; at light loads it approaches to a single-phase current.

The problem of producing a satisfactory polyphase from an alternating current has a special bearing upon the railway power question; for here we are practically limited to the alternate current for long-distance work, and we are also practically limited to a single wire or conductor for conveying the energy from the line to the track. The satisfactory solution of the problem therefore turns on the production of a satisfactory motor or means for operating the motor from a monophase circuit, such that the motor shall start easily under full load; and that solution has not yet, apparently, been forthcoming.

Having now considered the principal stationary apparatus which have been devised for effecting different forms of

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[22] *Trans. A. I. E. E.*, V. 12, p. 505, September 25, 1895.

current transformation, we are prepared to return to machines having moving parts, of which the most important is

THE ROTARY TRANSFORMER.

The Two-Coil Transformer.—Under this head we include all those machines which resemble the dynamotor in having a single field and a two-coil armature, but which are intended to be used with an alternating current in one or both coils. The distinction, as we shall see, is an essential one. In fact, these machines belong more properly to the rotary-transformer class than to the dynamotor class, as the armature reactions and much of the mathematical theory are common to both.

The machine shown in Plate XVI, which is the same as that heretofore referred to (see pages 226* and 263), is from a patent issued to Van Depoele[33] in 1882, and is apparently the first of either the dynamotor or rotary transformer type. It is interesting as an apparent near approach to the polyphase machine, although in fact it is more properly considered, so far as its secondary circuit is concerned, only an adaptation of the Gramme polyphase winding mentioned on page 263 above. The primary is of the ordinary closed-coil Gramme pattern, but the secondary is divided into four independent quadrants, one end of each being grounded on the frame, while the other is connected to a single slip-ring. The effect is to produce four independent line circuits, but with a common return (see diagram, lower figure). The patentee, however, did not observe the nature of the four-phase circuit thus produced, nor that the return wire was not necessary except as a regulator, as no current will flow through it when the load on each pair of opposite line-wires is equal.

The two-coil rotary transformer has at least three considerable advantages over the single-coil machine, to wit, that a pressure transformation may be made along with the species transformation; that the two circuits are entirely

* March number of this *Journal*.

[33] No. 257,990, of May 16, 1882.

independent; and that the two windings may be made on different plans according to the form most suited to the kind of current used in the respective circuits, as is done in the Van Depoele machine just explained. It has not, however, come into extended use, probably owing to the

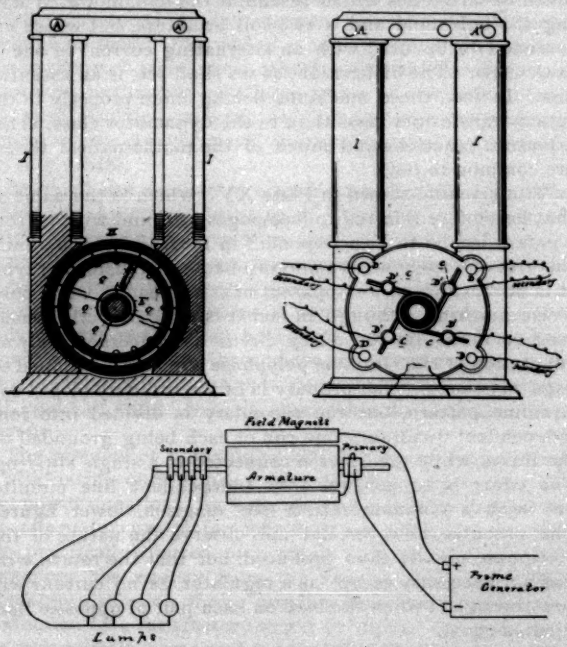

PLATE XVI.—Van Depoele's two-coil *D C* polyphase transformer. 1882.

fact that where a pressure transformation and species transformation are found desirable in one machine, the inductorium or stationary form with rotating commutator is deemed preferable.

We need not therefore delay longer upon this type,

especially as no very important improvements or varieties are set before us; we make, however, one exception, in the extremely interesting, ingenious and versatile machine invented by Lieut. F. J. Patten.[34] As this, however, is really only a variety or modification of his one-coil machine, it will be convenient to defer further explanation of it until after considering the properties of the one-coil transformer.

Where it is desired to run a pair of transformers to operate a three-wire continuous current circuit from a primary alternating or polyphase circuit, the two machines being connected up in parallel to the primary circuit, single-coil transformers are an impossibility, because, as pointed out by Field,[35] such connection, owing to the positive secondary terminal of one machine being joined to the negative secondary terminal of the other, would result in a periodic short-circuiting of the primary circuit. Hence in this case a two-coil machine must be used. Such a machine has been patented to Rice.[36]

A mode in which a single one-coil transformer may be connected to a three-wire system will be hereafter described (page 279).

The Single-Coil Rotary Transformer.—The single-coil rotary transformer may be defined as a two-coil transformer whose two coils have been made equal to each other and then merged into one. This is the standpoint from which we have approached it; but it is in no wise indicative of its origin. Indeed, so far from the two-coil having given rise to the one-coil transformer, quite the contrary is the fact; for, setting aside a few isolated machines—principally of the dynamotor order and intended, in general, only incidentally for dealing with alternating currents—which are disclosed by the patent records, the two-coil machine has only come into practical use long after the one-coil, and then only as an improvement over the latter for certain uses, as explained on the preceding page.

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[34] *Elec. World*, V. 26, p. 669, Dec. 21, 1895.
[35] *Proc. I. E. E.*, V. 27, p. 697, Nov. 24, 1898.
[36] No. 516,836, of Mar. 20, 1894.

As a matter of fact, the origin of the rotary transformer is quite different from and independent of that of the dynamotor. Its first appearance is not as a transformer at all, but as a dynamo adapted to produce both direct and alternating current according to the needs of its owner. Such a machine, according to Professor S. P. Thompson,[37] has been in the Finsbury Technical College since 1885. This machine consisted of a bipolar Gramme armature with ordinary commutator, with the addition of two insulated slip-rings at the other end of the armature, these rings being connected to two points on the winding at opposite ends of a diameter. Of its origin we are not informed; nor can we certainly say that the device had not been independently and contemporaneously employed by others. It was not, however, patented in this country until 1888, when a patent was issued to Bradley.[38] This machine is illustrated in Plate XVII. Here also it appears that the main object of the inventor was to increase the capacity of a Gramme-wound alternate-current dynamo, by utilizing the "waste space" on the armature, which occupies about one-half of its periphery. To this end he connects four slip-rings to symmetrical points on the armature, thus doubling its capacity (see *infra*, under "Output"), as he claims, each pair of opposite quadrants being alternately idle. The two *opposite* armature connections form the terminals of one circuit, the other pair those of another independent circuit. The machine is also provided with a commutator for producing direct current as may be desired, specially for exciting the machine. The patentee well recognizes the phase-relations of the two circuits, as well as of the several quadrants of the armature, and the constant nature of the flow of energy which he is thus enabled to obtain from the machine; but he only incidentally mentions its use as a transformer of energy. Yet it is to be noticed that this is a distinct advance over the

[37] *Proc. I. E. E.*, V. 27, p. 654, Nov. 10, 1898.

[38] No. 350,439, of Oct. 2, 1888. A patent for a three-phase machine (No. 409,450, of Aug. 20, 1889), otherwise identical with this one, was issued to the same inventor on a later application, filed Oct. 20, 1888—after the issue of the Tesla patents.

machine described by Thompson; and as the latter or single-phased device is not claimed by the patentee, it is clear that such a device must have been known before the date of his application, May 9, 1887.

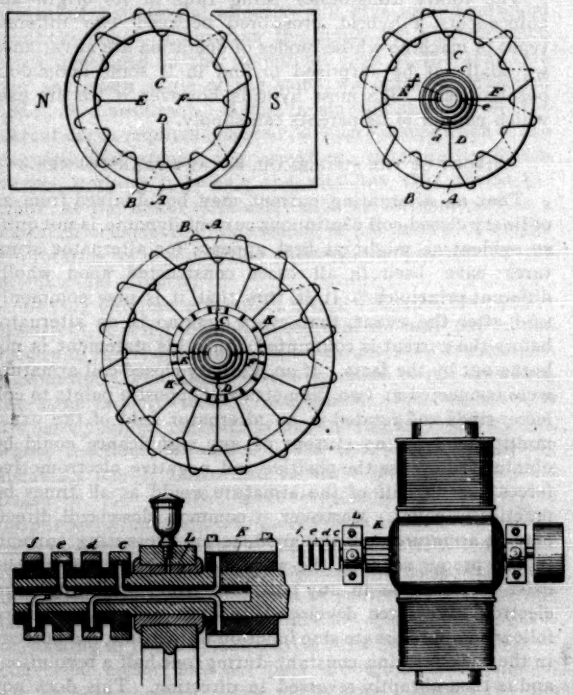


PLATE XVII.—Bradley's single coil rotary transformer. 1888.

Be the question of invention as it may, however, the apparatus was first brought practically and prominently to public notice by the German firm of Schuckert & Co., of Nuremberg, and also by Lahmeyer, at the Frankfort Exhi-

bition of 1891, where they exhibited several large three-phase continuous-current rotaries in actual operation, which attracted universal attention.[39] Since that time the rotary transformer has come into general use.

The rotary transformer being thus in its origin and antecedents a hybrid, cross-bred between two different types of machine whose modes of operation are at variance, we shall not be surprised to find in it some anomalous peculiarities. Like most hybrids, however, it has its uses which neither of its parents can supply.

THEORY OF THE SINGLE-COIL ROTARY TRANSFORMER.

That an alternating current may be obtained from an ordinary closed-coil continuous-current dynamo is not quite so evident as might at first appear; for alternator armatures have been in all cases constructed upon wholly different principles.[40] It is true that it is now commonly said, after the event, that every dynamo is an alternator before the current is commuted; but this statement is not borne out by the facts. If an ordinary closed-coil armature were connected at two diametrically opposite points to collector-rings and rotated in an alternator field of the usual multipolar type, no current of any significance could be obtained; because the positive and negative electromotive forces in each half of the armature would at all times be practically equal. Moreover, a common closed-coil direct-current armature does not produce an alternating current, in the proper sense of the word, nor does such a current exist at any time in any individual coil; for though the electromotive force developed in each coil does or may follow an approximate sine function of the time, the current in the coil remains constant during one-half a revolution, and is then abruptly reversed in direction. This does not happen to all the coils at once, but to each one successively at equal intervals of time; so that, if an alternating current

[39] Described by W. B. Esson in *Electrical Review* (London), V. 29, p. 529, November 6, 1891.

[40] Thompson, "Dynamo-Electric Machinery," 4th ed., p. 640.

is to be got from such an armature, it must be a new and different current, whether superposed upon it or otherwise independent of it. The principle upon which a true sinusoidal alternating current is obtained from such an armature depends upon the mathematical theorem that the integral of a sinusoidal quantity will give us a sinusoidal quantity; hence, integrating the sinusoidal electromotive forces developed in the individual coils of the armature over any given angle of the same, we obtain a sinusoidal E.M.F. as a resultant. Hence, a sinusoidal form of the current curve requires a sinusoidal space-distribution of the magnetic flux around the armature; whereas, in direct-current working, it is only the total-flux that affects the E.M.F. at the motor-terminals; this, as we shall see, is a matter of considerable importance in the design of single-coil rotaries, as it affects the ratio of the pressure in the two external circuits.

Having obtained a machine which will yield two species of current, it is not difficult to see that we may put in one species to run it as a motor, and take out the other as from a generator. The theory of the machine is not, however, the same in both cases. As a dynamo, the two currents are merely added together or superposed in the armature, whose reactions, resistance losses, etc., are thus, broadly speaking, merely those due to their joint effects. This phase of the problem, more especially with respect to output and armature heating, has been treated mathematically by Woodbridge and Child.[41] But when the machine is used as a transformer, the two currents run, in general, in opposite directions, and must be subtracted; so that the resistance losses in the armature are greatly diminished; or, looking at it in another way, a large part of the current converted either does not pass through the armature at all, or only through a few of its coils. Herein lies the

[41] *Elec. World*, Vol. 31, pp. 12, 216; January 1st and February 12, 1898. The authors of this article found that, for a *two-phase* and *D C* connection, the output of the machine when generating both kinds of current was actually somewhat greater than when generating only one kind, and the armature heating less for the same output.

great superiority of the one-coil over the two-coil transformer. We lose, however, the advantage of a possible pressure transformation, the ratio of the effective pressures in the two external circuits being substantially fixed for any individual number of phases, or division of the armature.

We may divide our consideration of the one-coil transformer into the following heads: Continuous-alternating and alternating-continuous current working; Phase relations; Pressure relations; Pressure adjustment; Pressure regulation; Current relations; Output; Efficiencies; Hunting; with a brief examination of two-coil theory where it differs materially from that of the one-coil machine.

Continuous-Alternating and Alternating-Continuous Current Working.—Not only is the theory of the machine used as a dynamo different from that as a transformer, but, if one of the two currents be continuous, the case where the latter is the motor or primary is not the same as where it is the generator or secondary current, in that the action of the machine is different in the two cases. While the principles of the dynamotor, as explained on pages 228* ff., apply in a general way here also, especially as regards the self-neutralization of the armature reactions, the introduction of the alternating current upon one side introduces new complications. If the continuous current be on the primary side, the speed of the machine, and hence the frequency of the alternating current produced, naturally depend on the field-excitation and the pressure in the primary circuit, and both will rise and fall together with the latter, as well as with variations in the field-strength. The difference between the primary voltage and the counter-E.M.F. of the machine as a generator, necessary to compensate armature losses and keep the machine running, is accounted for in the secondary circuit by just sufficient phase-lag in the *current*, caused by increased self-induction, to bring the ohmic E.M.F. down to the proper level. This case, then, presents little difficulty, other than the necessity of keeping the speed strictly con-

* March number of this *Journal*.

stant, to preserve a constant frequency of alternation in the secondary circuit.

The case where the continuous current is the secondary, and the primary alternating or polyphase, is somewhat more complex, as it is also much more frequent in practice. This is due to the fact that, whatever the counter-electromotive force produced by the machine and generated in the secondary circuit, the machine must run in synchronism with the primary circuit, or not at all. If, then, so running, this counter-electromotive force is greater or less than that of the primary mains, the current will adjust itself automatically to the proper lead or lag necessary to secure equality of the two, while at the same time the armature currents react upon the field to assist in securing such equality. If the counter-electromotive force of the machine at synchronism is greater than that of the primary circuit, the current will lead, and the reactions will oppose the field; if less, the current will lag, and such reactions will act to increase the field-strength. So far will this action go, that if the load be sufficiently light, the machine will run without field-excitation, by the mere reaction of its armature coils. Thus the machine is to a certain extent self-regulating; but if the lead or lag of the current is unduly increased, the wattless current and armature losses become very large and the effective volts so small that the machine will fall out of step and come to a stop.

It is an interesting fact that all one-coil rotary transformers whose fields are excited from the secondary or direct current winding are self-starting on open secondary circuit. In the case of a polyphase primary, this is due, of course, to the rotary field; but in the case of a monophase primary, to the fact that when starting they act like a direct-current motor in the same case (*i. e.*, when connected in an alternating circuit); the current in fields and commutator being simultaneously reversed, the torque remains constant in one direction; and this condition is maintained until the armature has reached synchronism.

Three-Wire Working.—While, as already pointed out on page 273, two rotary transformers cannot be connected up in

parallel on the primary side, and to a three-wire *D C* system on the secondary side, there is an interesting mode, invented by Dobrowolsky, in which a single rotary transformer can be made to supply both sides of a three-wire system where it has an alternating or polyphase primary. This is done by joining the brushes of the transformer on the secondary side to the outside wires of the three-wire circuit respectively, while the neutral wire is connected to a neutral point on the *primary* side of the transformer, formed by joining each wire of the polyphase circuit thereto through a reactance coil, in star connection. This mode is utilized by Dobrowolsky in the case of an ordinary *D C* dynamo by adding thereto two slip-rings and connecting them by a choke-coil, to the central point of which the neutral wire is attached. It would not seem to be very advantageous where large unbalancing occurs. The current in the neutral is an alternating one having a frequency n times that of the primary circuit, where n is the number of slip-rings.

Another mode is to wind the machine with two independent coils, each connected to an independent primary (alternating) circuit, and connected in series on the *D C* side, two commutators being required. In the case of a two-phase primary, one coil may be connected to each phase, where the two phases are independent. This was the method employed in the Alioth transformers for Geneva.[42] Of course, this would *not* be a "two-coil transformer," as the term is here used.

Phase-Relations.—The theory of phase-relations in a rotary transformer is very simple and easily understood. It is easily seen that the induced electromotive force in any one portion of the armature winding stands in the same phase-relation to that in any other portion as their angular separation on the ring. This, of course, refers to two-pole machines; for others we need only remember that the pitch of the poles is equal to 180 electrical degrees. Hence, to produce a polyphase winding of any desired number of phases, we naturally divide the armature into the same number of

[42] *Electrician* (London), V. 38, p. 340, January 8, 1897.

symmetrical portions and connect a slip-ring to each point of division.

It is here to be noted, however, that portions of the armature in opposite phase, that is to say, on opposite sides of the armature, cannot, as in ordinary polyphase generators, be connected in series to increase the generated E.M.F. and lessen the number of leading-in wires, because this would result in short-circuiting the intermediate portions of the armature; in other words, we cannot treat the several circuits as independent. This is a point of great importance, especially in connection with three-phase circuits, because, as originally pointed out by Mershon [43] and later calculated by Kapp,[44] the output of the machine is very largely increased in proportion as we increase the number of phases. So that, in dividing the armature into *six* instead of *three* parts, we must simultaneously double the number of our slip-rings and the number of leading-in wires. This is accomplished by Mershon [45] without unnecessarily doubling the number of conductors in the transmission line, by simply keeping the three-phase secondary circuits of the static step-down transformer, at the delivery end, separate, so as to obtain three independent circuits, whose electrodes are accordingly introduced at respectively opposite points of the armature, just as in two-phase machines. In other words, with the closed-coil armature, the mesh-connection is the only one possible; and we should, in speaking of phases, consider the number of phases the same as the number of parts or segments into which the armature is divided. From this point of view, the ordinary monophase would be called a "two-phase," the ordinary two-phase a "four-phase," and the six-wire three-phase a "six-phase" connection; and to avoid ambiguity we shall retain this terminology. The angular displacement between the different phases is then in all cases the quotient of the circumference by the number of phases; thus, three phases are in

[43] *Elec. World*, V. 25, p. 684, 1895.
[44] *Elektrotech. Zeitsch.*, V. 19, p. 621, Sept. 15, 22, 29, 1898.
[45] Patent No. 556,359, of March 17, 1896.

ternature, four phases in quadrature, six phases in sexature, etc.

We should observe also that where the number of armature phases is even, so that there are two segments in opposite phase, and two slip-ring connections at an interval of 180°, there are two modes of connection of the external circuits, and two corresponding modes of dealing with the machine mathematically; that is to say, we may either form a separate circuit of each pair of adjacent armature connections right around the ring, and so form as many different circuits as there are slip-rings, or we may connect together each opposite pair of armature connections, and so form half that number. Similarly, we may consider the current in each segment as single, or as the result of several superposed two-phase (monophase) currents, formed by the latter mode of connection.

[*To be continued.*]

ELECTRICAL SECTION.

Stated Meeting, held Tuesday, April 10, 1900.

APPARATUS FOR POWER DISTRIBUTION FROM CENTRAL STATIONS.

By Charles F. Scott,
Chief Electrician, Westinghouse Electric and Manufacturing Company.

The recent tendency in the commercial and industrial world is toward combination and concentration. Many small companies and many small factories are placed under one management, with gains in economy and efficiency. The combinations of capital have united many formerly competing electric companies and have thereby rendered it not only possible, but also imperative that the engineer shall bring the various generating stations and distributing systems into a single and comprehensive unit. Moreover, new enterprises dependent upon electrical operation are constantly being projected which far surpass prior undertakings in their magnitude and importance. The develop-

ment in the various machinery, apparatus and appliances which has recently taken place affords the means by which these large undertakings may be carried out.

It is not the purpose of the present paper to enter very far into the general engineering problems which present themselves in connection with modern central station practice, such as the arrangements with respect to the steam plant, the determination of the size of the units to be employed, the location of sub-stations and the various considerations which concern the conductors for the transmission and the distribution of current. It is, however, proposed to consider the various types of electrical machinery which are involved in a general system, including particularly generators, rotary converters and motors, and to show some recent types of construction and indicate some of the characteristics of their performance, particularly those of especial interest or importance.

DIRECT CURRENT AND ALTERNATING CURRENT.

A dozen years ago there was a bitter controversy in the field of central station engineering. On the one hand was the direct current system distributing at 220 volts with a middle or neutral wire; on the other hand was the alternating current system distributing at 1,000 or 2,000 volts with lowering transformers. One was well established, was simple and readily comprehended; the other was new, the principles of its operation were apparently abstruse and were not generally understood. Moreover, various dangers, real and imaginary, were attributed to the alternating current, and its possible usefulness was greatly limited because there was no suitable motor for power service.

The alternating current, however, continued to exist and has shown a remarkable development during the past ten years. It and the direct current have occupied fairly well defined fields. The direct current has usually been employed in central station work in the centers of cities where a very large volume of current is supplied within a comparatively short radius. The alternating current has found favor in towns and smaller cities where the service

is more widely distributed, and also in the outlying portions of cities which have a direct current system in the central portions. In a notable number of cases the alternating current has also been used throughout a city and has therefore monopolized the whole field. It can of course be used in the consumption circuits with especial propriety where the power is received in the form of alternating current over a transmission circuit from a distant water power.

During the past few years central station engineers have been encountering new problems which have, in a measure, brought to life the old controversy between the direct current and the alternating current, although in a different form. The magnitude of electrical work, the areas which must now be covered, the economies which are necessary in the generation of current and its distribution, bring new requirements. The wilderness of shafting, pulleys, belts and high-speed machines which did service some years ago has given place to stations with large direct-connected units; but even these are now becoming inadequate in stations for the generation of direct current for several reasons. The limited area over which current at low voltage can be distributed without undue cost for conductors makes it necessary to place the station at the center of the district to be supplied, and if this area exceeds a few square miles, it is necessary to erect additional stations. The supply of current to a large area therefore comes from a number of stations, and the economies of a large generating plant are not secured. Moreover, as these central stations should be located near the centers of their respective areas, they will usually be found in districts where real estate is expensive and where there is not the advantage of cheap transportation of coal and ashes which might be secured if the location of the station were selected with respect to its own specific function of generating current cheaply, and not on account of the necessities of the distributing system.

The direct current system has been forced to find a means by which the generating station can be advantageously located and the distribution of the direct current can be made from a large number of centers. The problem here

involved is one of voltage or pressure. For economic transmission over a considerable distance the pressure must be high in order that the current may be low and the size of the conductor small. On the other hand, for distribution in the consumption circuits the pressure must be low in order that it may be safe and adapted for lamps and motors. These relations are so well understood that it is needless to enlarge upon them. The cost of copper is, however, but one element, for cost of the insulation and lead covering of cables and the ducts for underground service make high voltage all the more imperative.

The requirement of the general system just outlined is that the current from the generating station shall be transmitted at high voltage through small conductors to various sub-stations or distributing centers, where the electrical energy shall be suitably transformed to a low pressure and an increased current.

There is no feasible and practical method by which direct current can be transmitted at a high pressure and reduced at sub-stations to a low pressure.

The alternating current, however, through the medium of the transformer can be varied in voltage, either increased or reduced at will in apparatus of almost ideal simplicity, without moving parts, with little deterioration and at a remarkably high efficiency. The direct current engineer has been forced to adopt the alternating current as a part of the general system and to generate and transmit current to various sub-stations as alternating current and then to convert it into direct current. This is now being done in many plants, both for supplying current at 220 volts, and also for supplying current at 500 volts for the operation of railways. In many cases where no general comprehensive system has been adopted, the alternating current has been used as an auxiliary, so that the various steam stations in a city have their capacity augmented by the supply of alternating current.

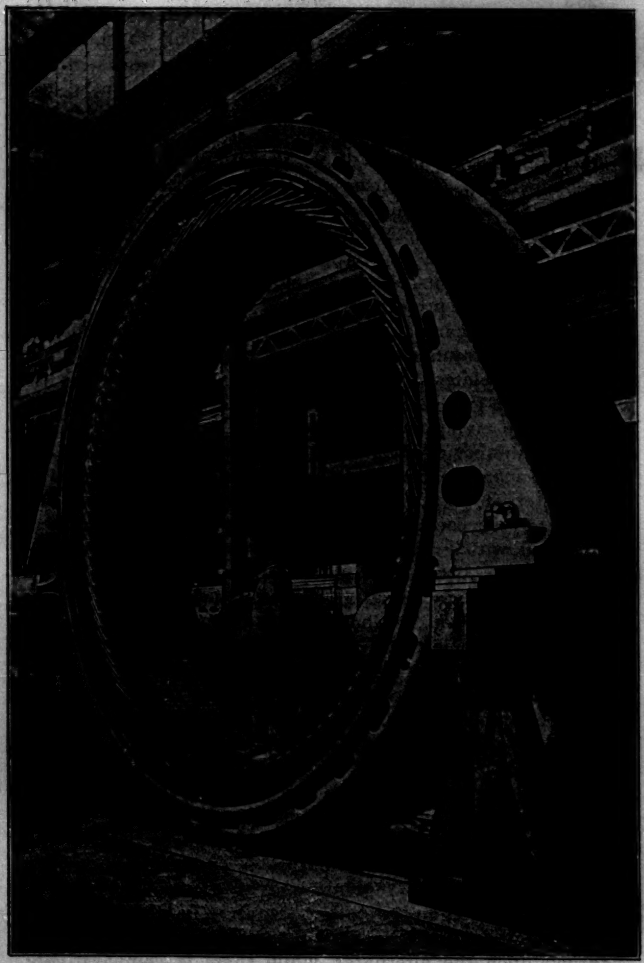
Even this relation between the direct current and the alternating current cannot be accepted as a final one, and as the best for universal adoption. The question naturally

arises as to the necessity or desirability of making the conversion from alternating to direct current. If all the current which is generated is alternating, it should certainly be retained as alternating current and distributed and used in this form if it is possible, and thus avoid incurring the loss in energy and the cost of apparatus and the attendance necessary for converting it into direct current.

THE ALTERNATOR.

The alternator of ten or twelve years ago, with its high-speed armature, with a surface winding held in place by treacherous band wires, would hardly be recognized as belonging to the same class of apparatus as the modern engine-type alternator. Belt and pulley have been discarded and the engine supplies the shaft and bearings. In many large machines the revolving armature has given place to a revolving field, which is constructed to have mechanical safety comparable with that of a fly-wheel, and in fact to perform the mechanical functions of a fly-wheel, thereby placing the fly-wheel exactly where it is required, without the strains which would otherwise come upon an intervening shaft. The stationary armature winding is laid in grooves or slots; it is not the hand winding of the olden time, but a succession of coils wound to exact dimensions on a lathe and insulated before being put in place, or else a succession of straight bars which can be shoved endwise into partially closed slots and joined at the ends by connectors of copper strap.

The most striking feature of the field is its simplicity and the excellence of its mechanical construction. In the construction employed by the Westinghouse Company a central spider of cast iron is surrounded by a ring of laminated soft steel plates. These plates are punched into sections 2 or 3 feet long, which include two pole pieces. The sections have projections upon their inner sides which fit accurately in dovetailed slots in the surface of the spider; the sections are built up overlapping so as to break joints, and when the laminated plates are built up to the proper thickness they are clamped together, a large



Stationary armature for 750 k. w. alternator.

number of bolts running through from end to end. The friction between the surfaces of the thin plates as well as the bolts through the holes gives a most substantial construction; the field is, in fact, a steel rimmed fly-wheel. The field coils are made of copper strap approximately $\frac{1}{16}$ inch thick by $1\frac{1}{4}$ inches in width, wound on edge, forming a single layer. The turns are then separated by asbestos soaked in shellac, and the whole coil is then baked, forming a solid and complete whole. These are placed over the field poles and are held in place by copper or brass wedges, which are in turn held by being placed in grooves along the sides of the projecting poles.

The stationary armature consists of a laminated ring which is surrounded by a cast-iron frame or yoke. The laminated plates are also provided with teeth and slots which form grooves along the surface of the armature suitable for receiving the conductors.

The number of slots in which the winding is placed has an important bearing upon the electrical performance of the alternator. A common form of alternator which immediately succeeded the old surface-wound armature was provided with a number of teeth equal to the number of field poles. A coil was placed around each tooth and a single-phase current was generated. The number of slots may be increased, so that instead of having a single coil for each field pole there will be several coils occupying the several slots, so that the resultant action will be produced by a number of coils coming under the action of a field pole at successive moments. The various turns in a coil are in this way separated into different slots, instead of occupying a common slot. It is well known that the self-induction of a number of turns of wire is much less if these turns are not placed close together in a common coil, but are separated and form several separate coils. It is also well known that the self-induction in an armature is a very important element in the voltage regulation of an alternator. For example, the voltage of a toothed armature in which there is high self-induction falls very considerably when a load is thrown upon the alternator, while there is comparatively

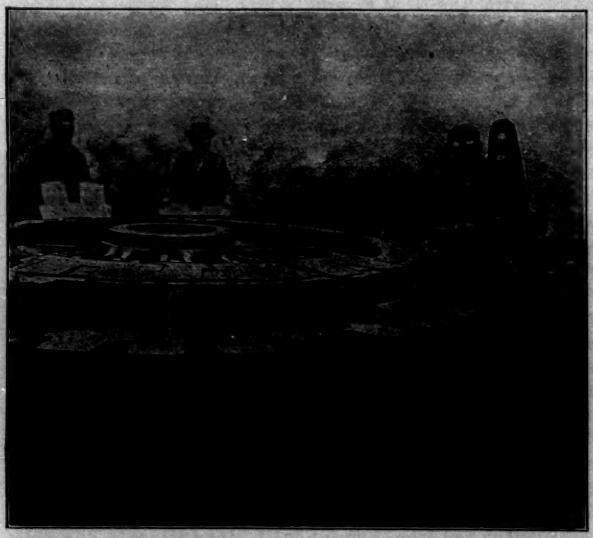
little decrease in voltage when load is thrown upon an alternator of similar proportions, except that the armature winding is placed in many slots. This difference in regulation is very marked when the alternator supplies current which is out of phase with the E.M.F. On this account, toothed armatures, which were quite satisfactory for carrying a load of incandescent lights, in which the current is in phase with the E.M.F. and which was subject to fairly slow and gradual changes in load as lights were turned on or off, is not admissible in power service, where the character of the current, frequently being out of phase with the E.M.F., is such as to produce a greater drop in voltage and in which the load is apt to be variable and to fluctuate over wide limits. While the number of slots in an armature is not the only element determining the regulation, yet it is a very important one, and in general an alternator with few slots per pole may be depended upon to regulate poorly, while one with many slots will in general give good regulation.

Excellent regulation is desirable, not only in order that a satisfactory service may be delivered to a fluctuating load, but also in order to insure favorable conditions for the parallel running of alternators, and in general for rotary converters or other apparatus connected with the system.

PARALLEL OPERATION OF ALTERNATORS.

The problem of parallel running is one which has recently come into prominence, because it has become a necessity in the operation of large power stations. This problem has been considered from a number of standpoints. The electrical conditions, including the various proportions of the alternators, such as their self-induction and their field reaction, the flow of idle or wattless current between the armatures, the relative field strengths, are all elements which have received more or less consideration and sometimes prolonged discussion. The speed of the engines, not only the mean or average speed, but the variation in speed during a revolution, also the weight of fly-wheel, are elements to which attention has been quite properly directed.

I purpose, however, considering the problem from a little different standpoint from those mentioned and not take up alone the voltage or current or speed, but to go at once to that fundamental element for which everything else exists, namely, the power. We will for the present omit the functions of the system other than its function of receiving



Building up the laminated pole pieces for a revolving field alternator.

power from two or more prime movers and delivering it to a common circuit.

We will assume two similar engines carrying similar alternators upon their extended shafts which are connected to common bus-bars and supply an outgoing circuit.

We will also assume two similar engines carrying similar gear wheels upon their extended shafts which drive pinions upon a common shaft which supplies power to an outgoing

belt. The number of teeth in the gear wheels may be taken as equal to the number of poles on the alternator.

There is a certain elasticity in the electrical connection between two alternators which allows a relative displacement between the angular position of the two armature windings with respect to the field poles without injury, provided the displacement does not become too great. When there is a displacement there is a flow of current between the two armatures tending to pull them to a common position, and this force is proportional to the angular displacement. In the same way we may imagine the spokes of the gear wheels to be slightly elastic, thereby permitting a deflection amounting to a fraction of the pitch between two teeth. It is not necessary, therefore, that the two engine shafts occupy exactly the same angular position, but one may be slightly in advance or behind the other. The forces exerted by the two engines upon the countershaft will be different and there will be a force tending to a common position of the two quite similar to that in the electrical system.

The proper condition for connecting the second engine to the common shaft by means of the gear wheel when the first is running is obvious. The pinion should not be thrown into the gear wheel unless the engine has the proper speed and the proper angular position. If the speed of the two engines is not the same just before they are connected together, there will evidently be a severe stress exerted during the extremely short time in which it is necessary to impart the necessary energy to the fly-wheel and other moving parts of the slower engine in order to bring it to the proper speed. A difference in speed of 1 per cent. may involve very great stresses, as the speed must be equalized almost instantly. It is also evident that if the arrangement is such that the pinion and gear-wheel can be instantly forced together when the teeth have not the proper angular position the result will be in the nature of a blow in order to secure the proper angular position.

The corresponding conditions in the electrical system are also quite evident. If engines and generators are not

running at the proper speeds or have not the proper angular positions at the time that they are thrown together, very great stresses will be brought upon the electrical system in order to produce the proper speeds and positions almost instantly.

When the two engines are connected by gearing they must of course run at identical speeds. This is true not only in respect to the total number of revolutions per minute and to the time of a complete revolution, but the angular speeds during each revolution must be identical, except in so far as the angular positions may change on account of the flexible spokes with which the gear wheels are supposed to be provided. If an engine running alone were to vary in angular velocity during a revolution, then there would be no marked effect unless the variation were quite considerable. For example, if the engine drives the shafting of a mill, the speed would fluctuate slightly; if it drives a dynamo, the voltage delivered would vary with each revolution, but would hardly be noticeable unless the variation were sufficient to produce a fluctuation in the lights which may be supplied. In each case the engine would deliver power at a very nearly uniform rate throughout the revolution. But when two such engines are connected by gearing and one tends to be in advance of the mean position when the other is lagging behind, then they cannot deliver practically constant power throughout the revolution, for the leading machine will tend to carry the greater part of the load, and if the natural fluctuation in speed is sufficient it may even take the whole load. When a part of a revolution is passed the conditions have changed and the second engine takes the undue proportion of the load. If the two engines were belted to a common shaft, the stretching and slipping of the belt would aid the equalization of the load so that each engine might be carrying a very nearly constant load.

In the electrical system the analogy is obvious. There will be a corresponding shifting of load from one outfit to the other, similar to that which occurred when the engines were connected by gearing instead of by alternators. If the

electrical connection were made not by alternators but by direct current machines, in which there is no requirement as to relative angular position, then each engine and generator would carry very nearly constant load throughout the revolution.

The above considerations indicate that engines for parallel running must be such that when running alone the angular displacement from perfectly uniform rotation must not exceed certain reasonable limits. These limits are determined by the number of poles in the alternator or the number of teeth in the gear and also the angular displacement which may occur without introducing undue stresses in the connecting system, *i. e.*, the current between the alternators in one case and deflection of the steel spokes of the gear wheels in the other case must not be excessive.

The gear wheel in one arrangement and the alternator in the other are simply means for transmitting the power developed by the engine. It is essential to keep this simple proposition clearly in mind, as it is sometimes imagined that the power in the electrical system can be regulated or controlled by means of the electrical adjustments of the alternators. In cases where this may be effected, it is because some new adjustment of the engine governing apparatus has been caused thereby, which in turn results in a change of the power developed by the engine. The alternator, like the gear wheel, simply transmits the power received from the engine. The power developed by an engine is primarily due to the adjustment of its valves. The valves, valve gearing and the governor must necessarily be looked to as quite important in parallel operation. The requirements upon these elements for parallel running are considerably different from those in other service.

Proper division of load between engines operating in multiple must therefore be effected by the governing mechanism. It is sometimes supposed that engines will be well adapted for parallel operation if they do not vary in speed between no load and full load more than say 1 per cent. Close speed regulation may be quite unsuited for parallel running. Thus, if one engine falls from 100 revo-

lutions to 99 revolutions per minute when loaded, and a second engine has the same excellence of regulation, but happens to have a speed falling from 100·5 to 99·5 revolutions, then it is obvious that when running at 99·5 revolutions one engine would be adapted for carrying half load and the other for carrying full load. A difference of only ½ per cent. in the natural speed of such engines may tend to a very unequal distribution of load. On the other hand, if each engine falls off 4 or 5 per cent. between no load and full load, a difference of ½ per cent. or 1 per cent. in their absolute speeds for a given load would cause only a trifling difference in the loads which they would carry when operating at equal speeds. It has been found in practice that usually much more satisfactory results are obtained when the speed falls off considerably, and that from 3 or 4 to 5 or 6 per cent. is desirable for good operation.

In considering the effect of fluctuation of angular velocity it was found that the load may rapidly shift from one engine to the other, due to the fact that the speeds must be maintained practically identical, although the natural tendency of the engines may be to produce fluctuating speeds. One engine is momentarily relieved of a part of its load; the ordinary requirement is a readjustment of the governor. The governor mechanism may therefore change its position to give a decreased admission of steam. A moment later the conditions are reversed and the engine takes more than its share of the load, thereby tending to give a different adjustment to the governor. The effects of angular fluctuation, however, are necessarily small and rapid and are not so apt to produce instability in the governing mechanism as certain other causes which may exist even though the engines have so uniform a turning effort and fly-wheels of so great weight that the fluctuation in angular velocity is inappreciable.

Two engines may be delivering equal power to a constant load either through gear wheels or alternators. The load may be suddenly changed. The change in load, either through a momentary increase of speed or other action upon the governors, causes them to act and readjust

the valves. When an engine running singly has a change in its load, the governor changes, often going beyond the required position, then returning a little too far, and after several oscillations settling to the proper position. The

Portion of a rotating field showing coils in place.

engine during this time is carrying its new load constantly and seeking to adjust itself to this new load. When two outfits are running in parallel and two governors are simultaneously seeking the new position required by

change in load, it is easy to see how neither governor is left free to find its new position (as it would be if the engine were running singly), because the load may be continuously shifting from one engine to the other. The two governors will have a mutual effect upon each other, as the load on each engine is not constant, but is partly dependent upon the governor of the other engine. If therefore the governors are oscillating back and forth about a mean position, it is easy to see how this oscillation may increase in amount. If one governor has moved beyond the proper position and is admitting too little steam, it should then readjust itself for the proper load. But at the same moment the other governor may be in a position which admits too much steam, thereby causing its engine to deliver too much power and thus carry load which should be carried by the first engine. The governor of the first engine, which is already carrying less than the proper amount, may, on account of the decreased load, seek to adjust itself for still less load. This causes a still wider divergence between the two governors, and presently they may both tend to swing back and pass the mean position. The interaction of the governors may thus continue and increase in amplitude until the shifting load from one engine to the other, caused by oscillation in the governor mechanism, may be far beyond permissible limits.

It will be well to consider the conditions which prevail when alternators are driven by water-wheels, where, as it is well known, parallel running is comparatively easy. Water-wheels in general give uniform rotation without the angular fluctuations which occur in steam engines having reciprocating parts and an intermittent admission of steam. The speed regulation of water-wheels is comparatively poor, and the governors are comparatively slow in action. A load gradually applied may make little change in speed, whereas, a suddenly applied load may cause a momentary decrease in speed which will be quickly recovered.

The governor of the steam engine is often prevented from oscillating by making it sluggish in action by the use of a dash-pot. The dash-pot must allow the freedom of

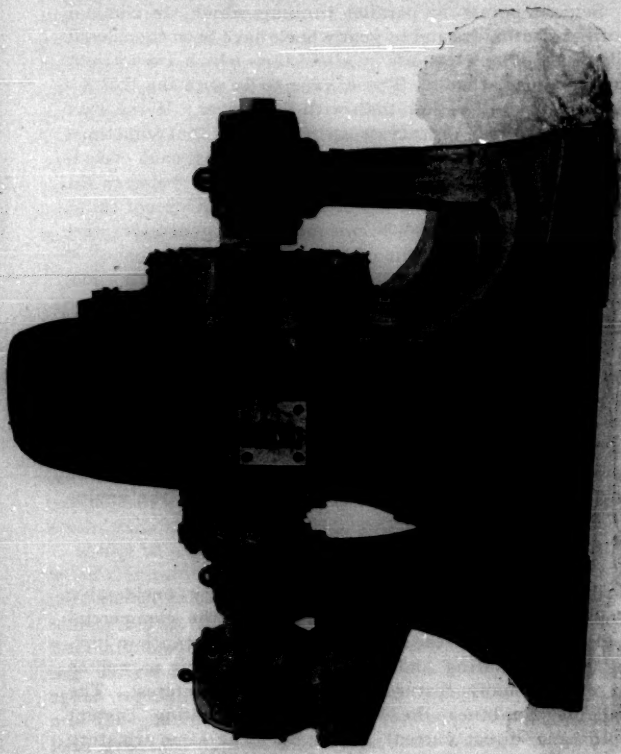
motion essential for regulation under changing load, and yet destroy the delicacy and sensitiveness which produce oscillation and hunting.

Several points in parallel running which are common both to alternators and to gear wheels have been considered. There are some elements in alternators which are not common to gear wheels. These have to do with the E.M.F.'s and the currents rather than with the power. If the wave forms of the two alternators are not similar, but sometimes one and sometimes the other E.M.F. during each cycle is higher, there will be a local flow of current between the two armatures. Again, if the field currents are not equal, the E.M.F.'s would also be unequal if the generators were running separately; but if the armatures are connected with a common bus-bar, the E.M.F.'s are necessarily equal and an armature current circulates between the two machines which equalizes the induction in the two machines, as the phase of the current is such that it assists the weaker field current of one machine and opposes the stronger field current of the other machine. This is a so-called "wattless" current; its function, like that of the field current, is for magnetizing, and it does not transfer power. It therefore has no mechanical analogue in the gear wheels and is not an element with which the engine need concern itself.

THE ROTARY CONVERTER.

The rotary converter is a machine of very considerable interest, as it has only recently entered the commercial field, and as it proves to be of so great importance in linking the alternating and direct current systems, as well as presenting many features of engineering interest. The machine combines the function of alternating current motor and direct current generator. The same armature and the same winding are used in both functions, thereby not only combining two armatures into one, but combining them in such a way that an armature of given size has a greater output as a rotary converter than it would have either as a motor or a generator. The common facts regarding the

rotary are well known; thus, the alternating current may be introduced as 2-phase or 3-phase; there is a definite ratio between the alternating E.M.F. and that delivered by the

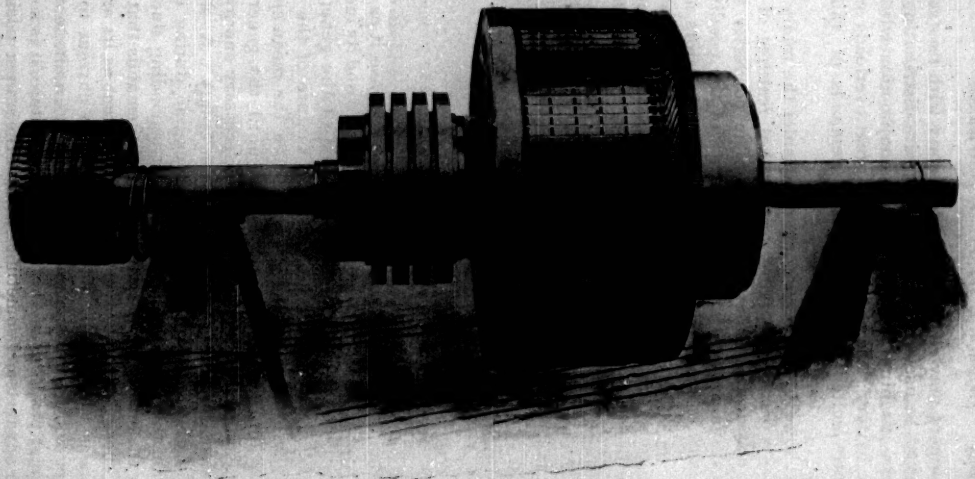


Rotary converter complete with starting motor.

commutator; the E.M.F. of the direct current may be varied by any suitable form of alternating current regulator; a middle wire carried from the secondaries of the lowering

transformers may enable a 220-volt rotary with two sets of brushes to be used for supplying a 3-wire distributing system; the machine may be used in conjunction with the storage battery; it is capable of very great overloads and is eminently suited for the variable demands of railway service.

It is, however, when we come to consider the rotary converter as a part of a working system that features of particular engineering interest appear. The converter must run as a synchronous motor, and many of the conditions which pertain to the parallel operation of generators apply also to the running of the rotary. The manner of connecting it to the circuit when it is started by a separate motor, or by a direct current to its own commutator, is similar to the connection of an alternator to the bus-bars in that the machine to be connected must have the proper speed, the proper phase relation and the proper E.M.F. before the switch is closed. The armature of the converter by its inertia tends to run at a uniform speed. If the speed of the generator is fluctuating, then the armature of the converter will attempt to follow that of the generator and will be successively accelerated and retarded. If the armature of the converter were without weight, it would be free to follow the fluctuations, but as that is not the case, it cannot fluctuate exactly with the generator armature and its inertia will cause it to lag behind the position of the generator armature. At a given moment the armature of the converter may be retarded and running below the mean speed. It will tend to continue at this speed until the generator speed has increased and supplies the necessary energy for quickly accelerating the speed of the rotary. A slight change in the angular velocity of an engine during each revolution therefore tends to cause corresponding fluctuations in the speed of the converter which demands that the flow of energy to the converter be intermittent as its armature acts as a fly-wheel. This increases the current to the converter, and as its armature cannot follow simultaneously the angular positions of the generator armature, it is sometimes in advance and sometimes behind the proper position



Armature of rotary converter.

for commutation, thereby tending to cause sparking or flashing at the brushes.

The converter does not take kindly to these fluctuations and treat them passively. It has a freedom of action of its own. When the generator attempts to force the armature to oscillate rapidly by the mean position there are various reactions within the converter which may respond to the tendency to vibrate or oscillate, and the armature may act as a pendulum and increase its amplitude of vibration. As the result, each oscillation may be a little greater than the one preceding, so that each time the armature falls behind or advances beyond the mean position it is a little further than before, until stable conditions are reached and it continues to vibrate through a fixed arc, or until the amplitude is so great that the armature is no longer able to remain in synchronism.

A means of preventing hunting which has proven to be very effective utilizes a very simple principle, namely, that of introducing a resistance to the oscillation of the armature, and thereby preventing the wide fluctuation in the same way that a dash-pot tends to prevent ordinary mechanical oscillation. The current in the armature produces a comparatively slight magnetic field which is stationary with respect to the field poles when the armature rotates synchronously, but when the armature oscillates back and forth, thus being alternately generator and motor, the armature current causes a varying field, which induces currents in the faces of the field poles which hinder the oscillation of the armature. If there are other metal parts near the armature surface, such as brass or copper bobbins for the field coils, currents may be induced in them. An efficient form is a copper shield around the field pole near its face, and extending over the face of the pole along the sides. The shields act as an electric damper whenever the armature begins to oscillate.

The converter will be much freer to set up oscillation if the force tending to hold its armature in close accord with that of the generator is comparatively weak. The force is smaller when the regulation of the generator is poor, and

the electrical connection between generator and rotary is much more rigid when the generator regulates well. The angular displacement between the position of the two armatures will be accompanied by a comparatively large current from the generator of good regulation, which will tend to prevent the fluctuations of the rotary.

From the above considerations it is clear that alternators driven by belt or by water-wheels tend to give more favorable conditions than those directly connected to engines for driving generators which supply current to rotary converters, as the angular speed will usually have greater regularity. Other rotary converters and synchronous motors, as they are generators of E.M.F. in common with the alternators, may become disturbing elements, and a converter which may run smoothly under other conditions may behave very badly when a synchronous motor or another converter connected to the circuit at some distant point is not operating properly. This is, however, not true of induction motors. They have an opposite effect, and their presence on a system facilitates the operation of the rotary and also the parallel running of the generators.

ALTERNATING CURRENT MOTORS.

The power service of a central station is of great and increasing importance. For railway work the direct current motor is used, and choice must be made between a number of stations generating direct current at 550 volts or a large alternating current power station, with sub-stations for converting to direct current. The latter method has been adopted in New York City, where large plants are now being installed.

For general power service, in which stationary motors are used, both direct current motors and alternating current motors are available. The direct current motor is well known, and places a high standard of excellence for its rival to equal or surpass.

The alternating current motor is not so well known, and the theoretical explanations and formulæ by which it is often elucidated only make it more vague to many minds.

The old controversy of induction *vs.* synchronous motors is solving itself. There are few, if any, who seriously advocate synchronous motors of very small size, say below 50 or 75 horse-power. In larger sizes the induction motor has been growing in favor until it is quite generally preferred up to several hundred horse-power, although there still exists a difference of opinion regarding very large sizes.

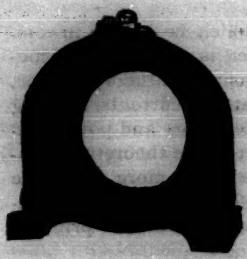
It is quite probable, however, that the synchronous motor will not be wholly displaced, for there are a few cases in which some of the peculiar features of the synchronous motor are so useful as to more than compensate for the increased mechanical and electrical complication, the greater difficulty in operation, the increased liability to interruption of service and the many injurious effects which it is capable of producing upon the system.

The induction motor, the form which is the one in common use for general power purposes, is unique in its mechanical simplicity. However confusing the theory may be, dealing with difference of phase, wattless currents, shifting fields, mutual induction, magnetic leakages and power factors, it is mechanically simple. But these theoretical features do not interest the customer any more than the thermodynamic principles and the heat cycle of a gas engine concern the man who wants it to run his printing press.

The accompanying illustrations show the form known as the Westinghouse Type "C" Motor, which is widely used. The cylindrical cast-iron frame carries an inner cylinder built up of rings of laminated iron. The slots along the inner surface contain coils of wire, which constitute the primary winding which is connected to the supply circuit. The rotating element has a large number of slots, partially closed at the top, containing copper rods or bars which are slipped in endwise. These bars are securely bolted at each end to a substantial metal ring. It is all so exceedingly simple that one must appeal to negatives to describe it and infer what it is by telling what it is not. It has no commutator, no brushes, no moving nor sliding contacts of any kind; there is no mechanical friction nor wear, except in the self-

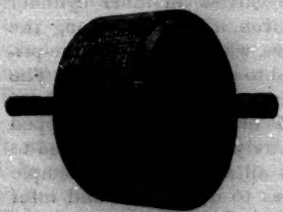
Cast-iron housing.

Primary ready for winding.



Primary completely wound.

Type "C" motor complete.



Secondary core.

Secondary complete.

CONSTRUCTION OF A TYPICAL INDUCTION MOTOR.

oiling bearings in which the shaft runs; there are no band wires, no delicate windings, no vital parts to be weakened or thrown off by centrifugal force. It is the presence of these things which makes necessary a large proportion of the cost of repairs and renewals and causes directly or indirectly most of the accidents and burn-outs which are incident to direct current motors. It is the absence of these things which makes the Type "C" motor the most nearly perfect mechanical form of motor which has been devised.

In electrical characteristics the induction motor and the direct current motor present some marked differences. In some features one, and in some features the other excels. A fair comparison must not be limited to a single element. The induction motor is not to be fairly judged by considering only its efficiency, or its power factor, or its starting torque, or its starting current, or its speed regulation, or its overload capacity. Nor is this all; it is not merely efficiency in power, but effectiveness in service; not electrical excellence, but mechanical reliability which is of first importance, particularly when motors are to be distributed broadcast in cellars, restaurants, offices, shops and factories, consigned to the tender mercies of janitors and office boys. The delay resulting from an accident to a motor in a machine shop or a printing office may cost as much as the motor itself or the power required to run it a year.

Although electrical performance is not the principal element in a choice between the direct current and the alternating current motor, yet it is important. The full load efficiencies of commercial motors are fairly equal, but at small loads the induction motor has a higher efficiency, notably in the small sizes where the brush friction of direct current motors is relatively high.

The induction motor is admirably adapted for meeting emergency conditions, not only on account of its mechanical construction and absence of commutator, but also on account of its electrical characteristics. It may carry an overload of two or three times its normal load for a short time without injury, and in case of accident, in which the motor is overloaded and brought to rest, no damage will occur for a

few moments, not until the motor becomes overheated. The current to the motor at rest is limited by its self-induction. Under similar circumstances a direct current motor would take an enormously great current (unless the current is automatically interrupted) and damage would result immediately. If for any reason the voltage be lowered or even interrupted for a moment, the induction motor will decrease in speed momentarily, but may continue its work without stopping, or, if it should come to rest, it may immediately start when the current is again supplied. This feature has proved to be of very great advantage in some important installations. Under similar conditions with most direct current motors the services of an attendant would be required for starting. The induction motor of the forms we are considering is ideal in that it admits of no adjustments nor tampering by the ignorant or curious. There are no brushes nor field rheostat to adjust, and the starting device, even if it be improperly set, will only cause the motors to start with greater current than would otherwise result, whereas a similar mistake with other motors might prove disastrous.

The speed of the induction motor has a perfectly definite limit within a few per cent. of its ordinary running speed; no accident can cause it to be higher. It is not uncommon for a failure in the field of a direct current motor to result in a high armature speed, which brings very serious results.

THE CENTRAL STATION OF THE FUTURE.

The progress in central station engineering indicates that the various characteristics of the alternating current which make it adapted to the generation and distribution of electric energy have caused it to be recognized and adopted, so that we may look to the alternator as the form of generator which will be used in the future central station. When, however, we reach the consumption circuits, we find a divergence of practice, for the alternating current and the direct current are both adapted for this service. Each has its own particular characteristics and types of apparatus, each has its particular points of merit, and each has points in which it is not so good as the other. The

alternating current, however, possesses certain fundamental advantages, such as reduced cost for transforming apparatus, both in original investment and in attendance, reduced cost of conductors as the distributing system is supplied from numerous widely distributed transformers instead of being supplied from sub-stations, increased efficiency, and an ideally simple motor. The item of conductors for the distributing circuits becomes of very great importance where the conductors must be placed underground, and the cost of the copper alone may be small compared with the cost of the ducts or conduits in which the conductors are placed. Such items as these differ so widely in different cases that no general statement as to relative values can be made, but each case requires special consideration.

A peculiar difficulty confronts the engineer at the present time which makes the problem a double one. It is necessary on the one hand to utilize as far as possible the apparatus which now exists. This sometimes means the coöperation in one general system of many stations which were once entirely independent, each with its own particular class of apparatus and distributing circuits. This in itself is no easy task, but it is not sufficient to simply attain present results. There should be a plan which will lead to the ultimate system which will be the best. If apparatus is employed which is less efficient, more complicated and less reliable than other apparatus, it is usually simply a question of time when the change must be made from one to the other. It is obvious that the system and the apparatus which is most simple and reliable in its operation is that which will probably be adopted ultimately. The alternating system, therefore, has naturally the first claim to consideration, and upon the broad principles of simplicity it is the one which has the first place, and the burden of proof lies with the direct current to show adequate compensation for the cost and complication which its introduction involves.

We have considered the central station almost entirely with respect to the methods and the apparatus by which the energy of the engine is distributed for various industries and domestic uses, both for lighting and power.

The function of the electrical system is to convey power from the point where it is produced to the many points where it may be required. It is a distributor, it performs many of the same functions in a power system as the pipes in a system for supplying water.

Back of any electrical system there must be a supply of power, and any method by which the cost of power may be reduced must therefore be regarded as being of the very highest and far-reaching importance. The steam engine is recognized as less efficient for developing mechanical energy from coal than the gas engine, but while the latter involves great possibilities, it has not been used to any appreciable extent. Mr. Westinghouse is quick to appreciate the future possibilities of experimental beginnings; he recognized the possibilities of the alternating current, and it was he who was foremost in upholding it during the years of opposition and controversy. Electrical engineering in America is doubtless many years in advance of what it would have been except for his foresight and energy. He is now exploiting the gas engine and is bringing it to a state of mechanical perfection in which its inherent possibilities may be realized and an advance made in the cheapening of power which will effect an industrial revolution.

A few years ago one would have scarcely imagined that there could be operations more diverse and having so little in common as the lighting of our streets and houses, the lighting of street cars, the driving of printing presses and elevators and fans, the heating of street cars and cooking utensils and the making of ice, and yet to-day all of them may be effected by the current from a single power station.

The combinations of capital which tend to the concentration of the power and electric interests of a city into a single system; the development of electrical apparatus to meet the requirements of such a system; the prospect for cheapening of power; the development of the various means by which power may be utilized, are all factors which indicate that it is the central station of the future, from which is to come the energy upon which industrial life and social activity and advancing civilization depend.

RECONSTRUCTED GRANITE AS AN INSULATING MATERIAL.

[*Being the report of the Franklin Institute, through its Committee on Science and the Arts, on the invention of Thomas Wilkinson Blakey, of Keene, N. H., and Wm. Courtenay, of New York. Sub-Committee.—Geo. A. Hoadley, C. H. Bedell, Arthur J. Rowland, W. M. Stine.*]

HALL OF THE FRANKLIN INSTITUTE,
[No. 2122.] PHILADELPHIA, November 7, 1900.

The Franklin Institute of the State of Pennsylvania for the Promotion of the Mechanic Arts, acting through its Committee on Science and the Arts, investigating the merits of the Reconstructed Granite Company's "reconstructed granite used as an insulating material for electrical purposes," reports as follows:

Reconstructed granite is a manufactured product, produced substantially as follows: Natural granite chips are calcined by being brought to a high temperature and afterward pulverized. It is then thoroughly mixed with pulverized feldspar and kaolin in definite proportions; enough water is added to make the mixture plastic, and it is then moulded into the desired forms under heavy pressure. After being dried it is subjected to a temperature of about 3,000° Fahrenheit, at which temperature it is fused into a homogeneous mass. When used for electrical purposes, the surface is given a vitrified glazing, which aids in increasing its insulating properties by rendering it less porous. The claims made for this material are as follows:

(1) It is absolutely fireproof.

(2) It resists the action of all solvents and acids except hydrofluoric, which attacks it superficially.

(3) It is frostproof.

(4) It is non-porous, and consequently does not absorb moisture.

(5) It has high crushing and tensile strength.

(6) It has high insulating qualities.

In investigating this material, your committee has made use of, first, experimental tests, and, second, the testimony of extensive users of the various forms of insulation blocks produced.

From the tests made, the reports on the various claims are as follows:

Claim 1.—A piece of broken insulator was heated until it became red hot, when it was plunged immediately into cold water. The only observed effect was a slight checking in the glazing in an angle of the specimen.

Claim 2.—Found to be substantially correct.

Claim 3.—No tests were made of its resistance to the action of frost.

Claim 4.—A piece of the material was weighed in November, 1899, and found to weigh 1706·2 grains. It was then placed in water and kept there until October, 1900, when it was found to weigh 1719·2 grains. It was then dried and lost all its moisture except ·2 grain, weighing 1706·4 grains. Computing the amount of absorption we found it to be ·76 per cent. of the weight of the specimen.

Claim 5.—Three tests for crushing strength and four for tensile strength were made by a member of the committee, with the following results:

CRUSHING.

	Pounds per Square Inch.
Specimen A	5,312
Specimen B	12,290
Specimen C	11,612

TENSILE STRENGTH.

	Pounds per Square Inch.
Specimen 1	1,005
Specimen 2	820
Specimen 3	973
Specimen 4	867

Claim 6.—The report of this test can best be given in a quotation from the report of the member making the test: "I tested the samples of 'reconstructed granite,' both with a megohm Weston voltmeter under 550 volts, and also with our D'Arsonval galvanometer and fifty silver chloride cells.

One volt deflection on the voltmeter is equivalent to 550 megohms, while the D'Arsonval instrument registers thousands of megohms. The samples are beyond the range of either instrument before soaking. After removing the glaze and soaking in salt water for two weeks, we can just get a very slight movement of the needle on our megohm voltmeter. We are safe in saying that the ohmic resistance of these samples is very high."

The testimony of the different users consulted by your committee does not cover all the claims, but is in part as follows:

"We have been using it (reconstructed granite) for third-rail insulators in large quantities, and have, therefore, subjected it to numerous tests in regard to the absorption of moisture, break-down qualities at different potentials, strength, etc., finding it to be extremely variable. In the case of absorption as much as 7 per cent. of its weight is often taken up, while in other instances it is as low as one-half of 1 per cent. * * * By thoroughly baking and drying out the material we have been able to get a resistance as high as 8 megohms, but upon subjecting it to steam for twenty-four hours, the resistance was as low as 20,000 ohms."

Another extensive user writes: "We use the reconstructed granite in connection with our railway equipments for several purposes. One is to support the panels in the resistance boxes, and to support the cast grid resistances to angle irons fastened under the car. For these purposes we find it a good insulator, and stronger than any vitrified brick that we are able to get hold of. We also use this granite in the controller as an arc deflector. * * * Breaking the heavy currents that are necessary on heavy elevated work, that is, 250 ampères, is quite a problem, and we found nothing else that would do as well for a deflector as this granite." "It is also used extensively, I believe, altogether by the elevated roads in Brooklyn as an insulator for the third rail."

The tests and testimonies herein cited have caused your committee to believe that an invention of decided commer-

cial importance has been made, and in consequence of this belief the Franklin Institute recommends that the John Scott Legacy Premium and Medal be awarded to Thomas Wilkinson Blakey, of Keene, N. H., and William Courtenay, of New York, N. Y., for their "Reconstructed Granite as a Material for Insulating Purposes."

Adopted at the stated meeting of the Committee on Science and the Arts, held Wednesday, December 5, 1900.

JOHN BIRKINBINE, *President.*
WM. H. WAHL, *Secretary.*

Countersigned,
H. R. HEYL,
Chairman of the Committee on Science and the Arts.

NOTES AND COMMENTS.

PROTECTING BUILDINGS FROM FIRE BY A WATER CURTAIN.

The *Iron Age* is authority for the statement that the method of protecting buildings from fire by the use of what is called a "water curtain," by which water can be caused to fall in a sheet all around the structure, is steadily growing in favor. The same journal conveys the information that the great building of the Public Library of Chicago is protected on this plan. The arrangement, which is extremely simple, is described as follows:

A 7-inch steel water main is laid around the top of the structure, upon the broad stone table formed by the top of the coping. this pipe having connection with force pumps situated in the basement, and, through perforations properly arranged, insures the introduction of a substantial sheet of water from cornice to pavement, around the whole or any imperiled portion of the building. The arrangement of the system of piping is such as to permit of operating in prescribed sections; additional relays of smaller pipe are also placed in position above windows and doors in order to complete the curtaining of those points in the most serviceable manner, should the curtain in the main be broken by wind impinging against the building. W.

HOW SHOULD BOILER-HEATING SURFACES BE CALCULATED.

In a paper lately presented to the American Society of Mechanical Engineers, Mr. C. W. Baker questions the correctness of the usual practice of computing the horse-power of steam boilers from the heating surface. He affirms that by the method usually followed, there results an error of from 7 to 17 per cent., which, he says, is due to the practice of taking the surface in contact with the water, instead of that in contact with the fire gases, as the heating surface. Where these surfaces are flat there will be no difference between

one side and the other, but the boiler-heating surface is made up largely of tubes, and in these there is a difference of 17 per cent. between the interior and exterior surface in the case of a 1-inch tube, and of 7 per cent. in the case of a 4-inch tube.

The error to which Mr. Baker calls attention lies in the failure to appreciate the fact that the heating surface of the boiler, on which its steaming capacity depends, is the actual surface exposed to the fire or fire gases. With clean metal, the actual difference of temperature between the two sides of a boiler plate (or tube) is never more than 1° Fahrenheit, and Lord Kelvin has observed that for all practical purposes, we may consider that the heating surfaces of boilers conduct heat as though they were no thicker than paper.

It follows from the foregoing observations that the temperature of the heating surfaces of steam boilers is that of the wet side, and not that of the fire side of the plate (or tube).

Although this fact is common knowledge among engineers, Mr. Baker claims that it has been generally overlooked by engineers and writers on engineering subjects, who have not insisted, as they should, that the fire side of boiler tubes should be that from which heating surfaces should be computed.

He illustrates his argument by the statement that if the fire side of the tubes be increased by forming ribs upon it—as is the case with the Serre tube—the steaming capacity of the boiler is thereby increased; but no such increase of steaming capacity will result from the placing of ribs on the wet side of the tubes.

Mr. Baker further makes the interesting statement that a thin coating of scale on the wet side of a boiler plate affects the steaming capacity less than a furring of soot on the fire side, which will be something of a surprise to most engineers. Another deduction of the author is that circulation of water in a steam boiler is of much less consequence than is generally supposed in its relation to efficiency. Good circulation is desirable because of its influence in assuring the equal heating of all parts of the structure, and hereby preventing undue strains in certain parts, but in Mr. Baker's judgment it can have no effect on economy or efficiency.

The points made by the author seem to be well founded, and should receive the serious attention of steam engineers. W.

PUBLICATIONS RECEIVED.

Geography in the Elementary Schools. By W. T. Harris, U. S. Commissioner of Education. From the author.

Rules and Suggestions as to Plumbing Work and Drainage, Sewerage and Sewage Disposal, Water Supply and Fire Protection. From the publishers, The Engineering News Publishing Company, New York.

Sanitary Engineering of Buildings. By Wm. Paul Gerhard, C.E. Advance sheets. From the publisher, Wm. T. Comstock, New York.

Shot Iron; how to recover it and how to use it. By C. H. Putnam, Moline, Ill. (Reprint from *Am. Foundrymen's Assoc.*) From the author.

The Open-Hearth Continuous Steel Process. By Benjamin Talbot (Pencoyd, Pa.). From Mr. James Christie. (Reprint from *Jour. Iron and Steel Inst.*, No. 1, 1900.)

U. S. Geological Survey. Mineral Resources of the United States. Calendar years 1892–1899. From David T. Day, Chief of Division of Mining and Mineral Statistics.

A Comparative Study of the Methods Used for the Measurement of the Turbidity of Water. By George C. Whipple and Daniel D. Jackson. (Reprint from *Technology Quarterly.*) From the authors.

A Study of Certain Shades and Globes for Electric Lights as Used in Interior Illumination. By Wm. Lincoln Smith, S.B. Part I. (Reprinted from *Technology Quarterly*, Sept., 1900.) From the author.

Une Langue Universelle, est elle possible? L. Lean, Dr. es. S. Paris: Gauthier-Villars, 1900. From the publisher.

Cochrane Heaters, for heating and purifying water for boiler-feed and other purposes. Harrison Safety Boiler Works, Philadelphia.

Letters on Brewing. Edited by Hantke's Brewers' School and Laboratories, Milwaukee, Wis.

Electrical Aërial Cableways. Telpherage. Circulars 8, 9, 10. From the Consolidated Telpherage Co., New York.

Machine Tools and Attachments. Imp. 4to, 724 pp. Embracing metal-working and wood-working tools and their attachments. (Illustrated.) From Manning, Maxwell & Moore, New York.

Les Matières Colorantes Azotiques. Par Georges F. Joubert. Small 8vo. (Encyclopédie scientifique des Aide Memoire.) From the publishers, Gauthier-Villars, Paris.

Report on the Census of Porto Rico, 1899. Lt. Col. J. P. Sanger, Director. Washington Govt. Print. 1900.

Annuaire pour l'An. 1901, publié par Le Bureau des Longitudes. Avec des notices scientifiques. Paris: Gauthier-Villars. 1901. (Price, 1.50 francs.)

The Secrets of the Sun and the Starry Universe. By Henry Raymond Rogers, M.D., Dunkirk, N. Y. Read before the Young Men's Literary Club of Dunkirk, June 12, 1900. (Illustrated, 8 vo, pp. 31.) From the author.

Report of the Commissioner of Education. 1898–1899. Vol. I, 8vo, pp. vii–1248. Washington: Government Print, 1900. From the Bureau of Education.

The Metric System. A paper read before the American Chemical Society, June, 1900. By Mr. Rufus P. Williams, President of the N. E. Association of Chemical Teachers. (8vo, pp. 8.) From the Decimal Association, London, England.

Encyclopédie Scientifique des Aide-Memoire. Travail des Metaux dérivés du fer. Par L. Gages, Capitaine d'artillerie. Small 8vo, pp. 202. (Price, 2.00 francs.) From the publishers, Gauthier-Villars et Massan, Paris.

BOOK NOTICES.

Theory and Calculation of Alternating Current Phenomena. By Charles Proteus Steinmetz, with the assistance of Ernst J. Berg. Third edition, revised and enlarged. 8vo, pp. 525–xx. New York: Electrical World and Engineer, Inc. 1900. (Price, $4.00.)

This work, of which the previous editions have been fully noticed in the *Journal*, is well known to the electrical engineering fraternity as a valuable compendium of alternating current phenomena and their calculation in connection with the design of alternating current machinery. In the present third edition, the treatment of the subject, more especially in relation to its application in engineering, is brought down to date. A number of new chapters have been added and many others have been more or less completely revised and enlarged. In its present form it will be welcomed by the electrical engineering world as a thoroughly modernized treatment of this important subject. W.

Mesures électriques. Leçons professées à l'Institut électrotechnique Montefiore, annexé à l'Université de Liège. Par Gérard (Éric), Directeur de l'Institut électrotechnique Montefiore, Professeur à l'Université de Liège. Grand in-8 de viii–532 pages, avec 217 figures. Cartonné, toile anglaise; 1901. Paris: Librairie Gauthier-Villars. (12 francs.)

The work herewith mentioned is an expansion of the author's *Leçons sur l'Électricité*, previously noticed in the *Journal*. It is devoted specially to the consideration of electrical measurements, the fundamental ideas on which these methods are based, and the methods of their application. W.

Laboratory Instructions in General Chemistry. Arranged by Ernest A. Congdon, Ph.B., F.C.S., Professor of Chemistry, Drexel Institute, Philadelphia (with 56 illustrations). Philadelphia: P. Blakiston's Son & Co. 8vo, pp. 110. (Price, $1.00.)

This work comprises a series of experimental studies to accompany a course in general chemistry. The scope of the work embraces the whole range of inorganic chemistry; and an appendix is attached covering a series of demonstrations in physical chemistry, to familiarize the student with laws and theories which form the basis of the science. The arrangement of the matter is substantially new and is very well done. The idea of interleaving the book to permit of the student incorporating therein notes of experimental work is also commendable. W.

Practical Lessons in Metal Turning. A handbook for young engineers and amateur mechanics. By Percival Marshall, Associate of the Inst. of Mechanical Engineers, etc. (With 193 original illustrations.) 12mo, pp. 166. London: Published for the proprietor of "The Model Engineer," by Dawbarn & Ward, Ltd.

This work is intended by the author as a practical guide for the amateur machinist and model-maker and appears to be well arranged for its intended purpose. W.

Victor von Richter's Text-Book of Inorganic Chemistry. Edited by Prof. H. Klinger, University of Koenigsburg. Authorized translation by Edgar F. Smith, Professor of Chemistry in the University of Pennsylvania (assisted by Walter T. Taggert, Instructor in Chemistry). Fifth American from the Tenth German Edition, carefully revised and corrected, with 68 illustrations on board and colored lithographic plate of spectra. (8vo, pp. 430–xv.) Philadelphia: P. Blakiston's Son & Co. 1900. (Price, $1.75.)

This fifth edition of a well-known text-book has been thoroughly modernized by the incorporation therein of the most recent well-established discoveries in the science, especially those relating to the general properties and the measurement of gases, the newly discovered constituents of the atmosphere, the modern theories of electrolysis, etc. W.

Franklin Institute.

[*Proceedings of the stated meeting held Wednesday, March 20, 1901.*]

HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, March 20, 1901.

President JOHN BIRKINBINE in the chair.

Present, 140 members and visitors.

Additions to membership since last month, 29.

Mr. George Washington, of New York, presented a description of his system of incandescent oil lighting, illustrating the subject by the exhibition of a large series of lamps showing the development of the invention. These lamps employ heavy mineral oil, supplied to the burners by air pressure, and burned on the Bunsen principle in contact with a special mantle of the Welsbach type. The light produced by these lamps is very brilliant, and they are adapted especially for out-door use or for the lighting of large enclosed areas, where electric arc lighting is now commonly used. The lamps are claimed to yield as much as 500 candle-power with the consumption of ⅛ of a quart per hour. Discussed by Prof. A. J. Rowland. The subject was referred to the Committee on Science and the Arts for investigation and report.

Mr. W. N. Jennings gave an account of his exploration of a newly-discovered cavern situated at Mapleton (near Huntingdon), Pa., and exhibited, with the aid of the lantern, a number of flash-light photographs of the interior, so far as it was possible to penetrate its recesses.

Mr. I. Newton Swope, of Mapleton, on whose property the cave was found, followed with an account of the manner in which the discovery was made. He stated that in making a blast in a limestone quarry which he is operating, an opening was accidentally disclosed, which, on being enlarged, gave access to what was subsequently found to be a cavern of evidently great but as yet unknown extent. A main passage has already been explored for a distance of 1,500 feet, and numerous lateral openings have been observed which evidently communicated with other extensive chambers, as a partial investigation disclosed. This conclusion also was strengthened by evidences

of the presence of a large flowing stream of water in immediate proximity to the explored portion.

There seems to be little doubt, from the preliminary and imperfect exploration of this cavern, that it will prove to be among the largest thus far found—excepting always the Mammoth Cave of Kentucky, which will probably always remain unique in this respect. It is of especial interest to notice in connection with the new discovery, that the various chambers and passages are richly decorated with stalagtitic and stalagmitic growths in great profusion, resembling in this respect the famous Cavern of Luray in Virginia. It is the intention of Mr. Swope to undertake at once a thorough exploration of the cavern, with the view of making it accessible.

The meeting passed a vote of thanks to Messrs. Jennings and Swope for giving the opportunity of hearing the first public announcement of this interesting occurrence.

The Secretary supplemented the remarks of the previous speakers by a few comments on the close similarity of the interior features of the Mapleton cavern with those of the celebrated Cavern of Luray, which, when he had the opportunity of visiting it, a few months after its discovery, was no more promising than this new one. He exhibited a few lantern views of Luray to afford the members the opportunity of comparing the two subterranean interiors. The similarity between them, in respect of the elaborate decoration of the walls and chambers, was quite noteworthy.

The Secretary called attention to an interesting exhibit of waste products derived from the operations of type founding, stereotyping, electrotyping, white metal working, etc., and a number of useful products obtained therefrom, which had been used to illustrate the presidential address of Mr. Joseph Richards before the Mining and Metallurgical Section; also a balance of Mr. Richards' design for automatically estimating the percentage of tin and antimony in such wastes.

An interesting historical relic, in the form of an old "fare register," was shown, which had been deposited in the Institute's collection by Mr. W. G. Deschamps, of Philadelphia. This apparatus was one of those used on the old omnibus line running in the early fifties, between the Stock Exchange and Frankford. The register is about 2 feet in diameter and weighing about 25 pounds, the face of the circular dial being elaborately ornamented by figures cast in brass, which are caused to go through the motions of striking a bell and an anvil when a fare is registered.

Adjourned.

WM. H. WAHL, *Secretary.*

STANDING COMMITTEES FOR THE YEAR 1901.

The President has made the following appointments:

COMMITTEE ON LIBRARY.

BENJ. S. LYMAN,	EDWIN S. BALCH,
F. L. GARRISON,	EDGAR MARBURG,
H. F. KELLER,	CHARLES J. REED,
ARTHUR FALKENAU,	LOUIS E. LEVY,
HENRY LEFFMANN,	GEORGE F. STRADLING.

COMMITTEE ON MEETINGS.

WASHINGTON JONES,	JOSEPH RICHARDS,
HENRY R. HEVL,	MORRIS E. LEEDS,
SPENCER FULLERTON,	CHARLES A. RUTTER,
JAMES CHRISTIE,	LEWIS M. HAUPT,
J. Y. MCCONNELL,	GUILLIAM H. CLAMER.

COMMITTEE ON METEOROLOGY.

GEORGE A. HOADLEY,	JOSEPH T. RICHARDS,
GEO. E. KIRKPATRICK,	HENRY GAWTHROP,
L. Y. SCHERMERHORN,	GEO. S. WEBSTER,
HENRY BIRKINBINE,	JOHN E. CODMAN,
JESSE PAWLING, JR.,	L. F. RONDINELLA.

COMMITTEE ON CABINET OF MODELS.

HENRY HOWSON,	FRANK SHUMAN,
JOHN F. ROWLAND, JR.,	CHAS. C. ADAMS,
PHILIP PISTOR,	A. M. GREENE, JR.,
L. L. CHENEY,	JOHN G. BAKER,
RICHARD GILPIN,	STRICKLAND L. KNEASS.

COMMITTEE ON CABINET OF MINERALS AND GEOLOGICAL SPECIMENS.

W. J. WILLIAMS,	ARTHUR J. ROWLAND,
WM. C. DAY,	LYMAN B. HALL,
E. V. D'INVILLIERS,	WM. H. GREENE,
THEO. D. RAND,	ANDREW A. BLAIR,
CLARENCE S. BEMENT,	F. A. GENTH, JR.

COMMITTEE ON CABINET OF ARTS AND MANUFACTURES.

THOS. SPENCER,	BENJ. H. GLEDHILL,
CYRUS CHAMBERS, JR.,	JOHN HAUG,
HARRISON SOUDER,	W. S. HARVEY,
JOHN F. SIMONS,	H. F. COLVIN,
HENRY J. HARTLEY,	A. E. OUTERBRIDGE, JR.

COMMITTEE ON SCIENCE AND THE ARTS.

[*Abstract of proceedings of the stated meeting held Wednesday, March 6, 1901.*]

MR. LOUIS E. LEVY in the chair.

The following reports were adopted:

(No. 2107.) *Improvement in Grate Bars.*—James Reagan, Philadelphia.

ABSTRACT.—This invention relates to grates of the rocking-bar type, its principal object being to keep the bed of fuel free from the clinkers and ashes that would ordinarily retard the admission of air to the combustion chamber. This is accomplished by a series of floating choppers which are borne by the rocking bars. For a description of the disposition of these choppers with reference to the rocking grate-bars and their mode of operation, the reader is referred to letters-patent of the United States Nos. 635,807–8, October 31, 1899.

By the use of this combination of devices, the inventor claims to be able to crush or dislodge all clinkers which are caught between the choppers and the

middle, end and intermediate bars of the grate frame, and to cut away and remove all ashes and masses of clinkers which form in the lower layers of the incandescent fuel. For general merit of the device, the Certificate of Merit is awarded to the inventor. [*Sub-Committee.*—John Hartman, J. M. Emanuel, Chas. A. Teal, Arthur M. Greene, Jr.]

(No. 2140.) *Pneumatic Clock.*—Augustus Hahl, Chicago.

This report is reserved for publication in full. An intelligible abstract is impossible without the aid of illustrations. The report of sub-committee is favorable, and recommends the grant of the John Scott Legacy Medal and Premium to the inventor. [*Sub-Committee.*—J. Logan Fitts, Geo. S. Cullen, H. R. Heyl, Lewis Breittinger.]

(No. 2160.) *Improved Threading Tool.*—Herman S. Dock, Philadelphia.

This report is reserved for publication in full. The report recommends the grant of the John Scott Legacy Premium and Medal to the inventor. [*Sub-Committee.*—Hugo Bilgram, H. F. Colvin, Lucien E. Picolet, A. Falkenau.]

(No. 2161.) *U. S. Standard Voting Machine.*—A. J. Gillespie, Rochester, N. Y.

(No. 2168.) *Bardwell Volometer.*—Arthur F. Bardwell, New York.

Neither of these reports is susceptible of abstract without the aid of illustrations. Reports in both cases are favorable. The award of the Edward Longstreth Medal of Merit is made. [*Sub-Committee.*—L. F. Rondinella, Geo. S. Cullen, Sam'l Sartain, Lewis M. Haupt.]

(No. 2169.) *Improved Sawing Machine and Guide.*—Frank A. Humphrey, Worcester, Mass.

ABSTRACT.—This invention is covered by letters-patent of the United States issued to applicant, Nos. 623,156 and 623,786, dated respectively, April 18 and April 25, 1899.

The invention relates to the class of sawing machines having a plurality of circular saws with swinging carriers and shifting devices adapted to bring the saws alternately to a common working position at the central opening of the work-supporting table that is adapted for tilting adjustment to both right and left inclination relatively to the plane of the saw when in working position.

The report, after dwelling upon the important features of the invention, concludes as follows: "A thorough examination of the state of the art * * * reveals the steps that have gradually led up to the * * * present invention. Its simplicity, compactness, ready adjustability to every class of work, thorough mechanical construction in both design and detail, and general convenience of operation, qualifies it to do most excellent work in large quantities."

The award of the John Scott Legacy Premium and Medal is recommended to the inventor. [*Sub-Committee.*—H. R. Heyl, T. H. Grigg, C. F. Albert.]

The following reports passed first reading:

(No. 2155.) *Improved Railway Tie.*—Philadelphia Railway Track Equipment Company, Philadelphia.

(No. 2158.) *Cash Register.*—The National Cash Register Company, New York.

(No. 2171.) *Water Sterilizer.*—The Forbes Company, Philadelphia.

The following cases were dismissed:

(No. 2190.) *Improved Mechanical Boiler Cleaner.*—Frank W. Hornish, Chicago, Ill.

(No. 2165.) *Steam Heater.*—The Prizer-Painter Stove and Heater Company, Reading, Pa.

A special committee consisting of Messrs. Fitts, Rondinella and Stradling was appointed to devise and submit to the General Committee a plan for a convenient method of indexing the committee's reports. W.

SECTIONS.

SECTION OF PHOTOGRAPHY AND MICROSCOPY.—The ninth stated meeting of Section was held Thursday, March 7th, at 8 o'clock. In the absence of the President, Dr. Leffmann was called to the chair. There were present 30 members and visitors.

Dr. I. N. Broomell read an interesting and instructive paper upon the "Use of Lantern Slides for Class Demonstrations." The speaker's remarks were profusely illustrated with an exceptionally fine series of slides, made by himself, and especially prepared for teaching dental anatomy, histology, etc. The thanks of the meeting were voted to Dr. Broomell.

Mr. John G. Baker exhibited a new and exceedingly ingenious and effective exposure meter of his own invention.

Dr. Leffmann made some useful suggestions as to the mounting and labelling of lantern slides, and exhibited some specimens embodying his ideas.

Mr. Frank V. Chambers, Editor of the *Camera*, Philadelphia, then introduced the subject of the Franklin Institute lending its patronage for the holding of a representative photographic exhibition, or salon, in Philadelphia, and after a general discussion of the subject, in which, among others, the following-named gentlemen took part: Messrs. Chambers, Leffmann, Sartain, Ives, Wager-Smith, Sawyer, the following motion was put and carried:

That the Executive Committee be instructed to consider the advisability of holding a general photographic exhibition in this city under the auspices of the Franklin Institute, and to report upon same at as early a date as possible, and that the Executive Committee be empowered to increase its numbers for this purpose. It was stated that the Art Club's galleries could be secured for such an exhibition.

F. M. SAWYER,
Secretary.

MECHANICAL AND ENGINEERING SECTION.—*Stated Meeting*, held Thursday, March 14, 1901. Mr. John F. Rowland, Jr., in the chair. Present, 34 members and visitors.

Mr. Cecil H. Taylor read a communication on "The Automatic Gun and its Military Aspects," which was referred for publication.

Mr. Henrik V. Loss presented a supplementary communication on "The Flow of Metal," answering some comments on his paper on this subject read and discussed at a previous meeting. Mr. Loss's communication was discussed by Mr. James Christie.

The subject was referred to the Committee on Publication. Adjourned.

DANIEL EPPELSHEIMER, JR.,
Secretary.